Appendix 1

LINDA LINGLE
GOVERNOR OF HAWAII

State of Hawaii

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

Office of Conservation and Coastal Lands
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

ALLAN A. SMITH
INTERIM CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

KEN C. KAWAHARA
DEPUTY DIRECTOR - WATER

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CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

REF:OCCL:TM

CDUP: MA-3380

Perry White
Planning Solutions
Ward Plaza, Suite 330
210 Ward Avenue
Honolulu, Hawaii 96814-4012

JUL 20 2007

Dear Mr. White,

SUBJECT: Conservation District Use Permit (CDUP) MA-3380

This letter is to inform you that on July 20, 2007, the Chairperson of the Board of Land and Natural Resources, pursuant to Chapter 13-5, Hawaii Administrative Rules, approved Conservation District Use Application MA-3380 for Meteorological Measurement Towers Located at Located at Olowalu-Ukumehame, Lahaina/Wailuku, Maui, portions of TMK: (2) 4-8-001:001 and (2) 3-6-001:014 subject to the following conditions:

1. The applicant shall comply with all applicable statutes, ordinances, rules, and regulations of the Federal, State and County governments, and the applicable parts of Section 13-5-42, Hawaii Administrative Rules;

2. The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury or death arising out of any act or omission of the applicant, its successors, assigns, officers, employees, contractors and agents for any interference, nuisance, harm or hazard relating to or connected with the implementation of corrective measures to minimize or eliminate the interference, nuisance, harm or hazard;

3. The applicant shall comply with all applicable Department of Health administrative rules;

4. Where any interference, nuisance, or harm may be caused, or hazard established by the use the applicant shall be required to take measures to minimize or eliminate the interference, nuisance, harm, or hazard within a time frame and manner prescribed by the Chairperson;

5. Any work done on the land shall be initiated within one year of the approval of such use, and unless otherwise authorized be completed within three years of the approval. The applicant shall notify the Department in writing when construction activity is initiated and when it is completed;

6. Should an impact with flying wildlife occur, KWP II shall remove the tower(s) until such time as the tower(s) are covered by an Incidental Take License and accompanying (amended) Habitat Conservation Plan;

7. Before proceeding with any work authorized by the Board, the applicant shall submit four (4) copies of the construction and grading plans and specifications to the Chairperson or his authorized representative for approval for consistency with the conditions of the permit and the declarations set forth in the permit application. Three (3) of the copies will be returned to the applicant. Plan approval by the Chairperson does not constitute approval required from other agencies;

8. The applicant shall obtain a land disposition from the Land Division for the proposed use;

9. In issuing this permit, the Department has relied on the information and data that the applicant has provided in connection with this permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part, and/or the Department may, in addition, institute appropriate legal proceedings;

10. Should historic remains such as artifacts, burials or concentration of charcoal be encountered during construction activities, work shall cease immediately in the vicinity of the find, and the find shall be protected from further damage. The contractor shall immediately contact SHPD (692-8015), which will assess the significance of the find and recommend an appropriate mitigation measure, if necessary;

11. The applicant understands and agrees that this permit does not convey any vested rights or exclusive privilege;

12. Best management practices for prevention of introducing exotic species to the site shall be observed;

13. Upon the end of the duration of data collection or the end of the equipment lifecycle or within three years, all equipment shall be removed and the land shall be restored to its original condition;

14. The applicant acknowledges that the approved work shall not hamper, impede or otherwise limit the exercise of traditional, customary or religious practices in the immediate area, to the extent such practices are provided for by the Constitution of the State of Hawaii, and by Hawaii statutory and case law;

15. Other terms and conditions as may be prescribed by the Chairperson; and

16. Failure to comply with any of these conditions shall render this Conservation District Use Permit null and void.

Please acknowledge receipt of this approval, with the above noted conditions, in the space provided below. Please have an authorized signature sign two copies. Retain one and return the other within thirty (30) days. A copy of the Staff report is included for your information. Should you have any questions on any of these conditions, please feel free to contact Tiger Mills at 587-0382.

Aloha,

Samuel J. Lemmo, Administrator
Office of Conservation and Coastal Lands

Receipt acknowledged:

____
Applicant's Signature

Date__________________

c: Chairperson
Maui Board Member
Maui District Land Office
County of Maui, Department of Planning

Appendix 2

Downed Wildlife Monitoring Protocol

INTRODUCTION

The primary objective of the Downed Wildlife Monitoring Protocol is to document injuries and fatalities of the four state- and federally-listed wildlife species covered by the HCP (the "Covered Species") during project operation, as a basis for determining the annual take attributable to the project. Monitoring will also document injuries and fatalities to other, non-listed species (including MBTA-listed species) to provide data on overall project impacts. While the primary risk to wildlife is considered to be in-flight collisions with project structures, all observed injuries and fatalities (e.g., vehicle strikes, predation, etc.) will be documented, regardless of cause.

The following protocol is based in part on the protocol originally developed for the KWP project, and has been refined and updated to reflect the lessons learned after nearly three years of monitoring at that project.

Important Considerations

As with the original KWP protocol, the methods outlined below are subject to continued refinement over the course of the project to increase effectiveness and efficiency of the effort. The protocol includes early, intensive monitoring of fatality rates that will include carcass removal and searcher efficiency studies, and development of a longer-term monitoring protocol based on the findings of the initial studies.

Three of the covered species are relatively large birds with adult wing spans in excess of 30 inches, and include Nene (*Branta sandvicensis*), Hawaiian Petrel (*Pterodroma sandwichensis*), and Newell's Shearwater (*Puffinus auricularis newelli*). Downed individuals of these species have been found to be relatively detectable at KWP. Large bird carcasses that more closely resemble Nene have not yet been used at KWP to evaluate the detection efficiency of searchers encountering larger carcasses. However, considerable insights have been gained using Wedge-tailed Shearwaters (*Puffinus pacificus*) to evaluate detection and carcass retention rates for medium-sized Procellariids. In contrast, the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) may be more difficult to detect during visual searches, and will require that surrogate species closely approximate the small size and cryptic coloration of this species. KWP II intends to implement trials using larger bird carcasses and smaller birds and/or mammals to examine variability in searcher efficiencies and carcass retention times.

An additional factor to be considered is the type of vegetation cover and terrain that exists within the search areas. Low, grassy cover and level bare topography are easiest for searching, and are expected to dominate in some areas as they do now at KWP. However, much of the KWP II search area comprises uneven terrain and a variety of different vegetation communities and ground canopy types. Although it has yet to be tried at KWP, vegetation management, for example by periodic mowing, continues to receive consideration as a potentially useful technique for maintaining the area around each turbine and met tower in a searchable condition. However, because short-mown grass might attract Nene to graze in the vicinity of turbines and other project structures, excessive vegetation management will be avoided. Finally, search methods continually evolve and new approaches are periodically introduced, which have the benefit of improving searcher efficiency and may result in time savings.

EARLY POST-CONSTRUCTION STUDIES

The field methods proposed below are based primarily on a refinement of the methods that have been used at KWP since operations began in June 2006 (Kaheawa Wind Power 2006). Other recent studies of bird and bat fatalities at wind power projects in the U.S. and Europe were also reviewed to develop and refine the previously-approved methods and search techniques (e.g., Kerns and Kerlinger 2004, Pennsylvania Game Commission 2007, Stantec 2008, Stantec 2009).

The initial period of fatality monitoring at KWP II will entail frequent, systematic searches of the area beneath each turbine, by trained technicians. Intensive sampling will proceed for a period of at least one full year, and will include the peak fledging periods of the subject species (seabirds in October-November and Nene in May-June). Depending upon the results, and in coordination with DLNR and USFWS, intensive monitoring may be extended beyond this initial period, modified and extended, or replaced with a less intensive monitoring protocol that has been developed based on the results of the initial monitoring.

Carcass Removal Trials

The objective of performing carcass removal studies at KWP II will be to determine the average amount of time an avian or bat carcass remains visible to searchers before being removed by scavengers or otherwise rendered undetectable. Carcass removal trials have been ongoing at the KWP facility since November, 2005. To date a total of 11 trials have been conducted using a variety of species and numbers of specimens, with carcass removal rates ranging from a few days to over two weeks and averaging 66% carcass retention by day 7. Similar but more frequent trials will be conducted at KWP II with the purpose of maintaining an ongoing record of scavenging rates that will best reflect the time of year and location that a take occurs. At least eight carcass removal trials will be conducted during the initial survey period, designed to enable two trials that correspond with each distinct season (fall, winter, spring, and summer) and will be used to adjust the number of estimated direct takes of covered species observed by correcting for carcass removal bias. Seasons will be defined as (a) fall (September-November), (b) winter (December-February), (c) spring (March-May), and (d) summer (June-August).

If using state or federally protected species as surrogates for trials, all state and federal laws pertaining to transport, possession, and use of these species along with appropriate animal use protocols will be followed. Carcasses used in the trials will be selected to best represent the size, mass, coloration, and if possible should be closely related to the four covered species. For example, Wedge-tailed shearwaters, a close taxonomic relative of the Hawaiian Petrel and Newell's Shearwater exhibit a close resemblance to both these covered seabird species, have been used successfully at KWP and elsewhere to examine carcass removal rates. All carcasses used for the trials will be fresh or freshly thawed. Dark colored mammals (e.g., rats, mice) and small passerines may be used to approximate the carcass removal rates of bats. Other types of avian carcasses that may prove useful for trials and would be desirable to obtain include locally-obtained road kills, downed seabirds, owls, and waterbirds, or species not protected by MBTA such as pheasant (*Phasianus colchicus*) and Rock Dove (*Columba livia*). Nene mortalities that occur elsewhere but render the carcasses available for carcass removal studies at KWP II would provide a valuable opportunity to learn how long Nene remain visible to searchers. Use of species protected under ESA or MBTA will require permission from DLNR and USFWS.

Each carcass removal trial will consist of placing a pre-determined number of carcasses (5-7 specimens) on the ground at selected locations in a random manner that approximates what would be expected if a bird came to rest on the ground after having collided with an overhead structure. The intent will be to distribute survey effort along the length of the project area to represent a range of elevations, habitat conditions (i.e. vegetation types), and seasonal variability. All birds are checked on days 1, 2, 3, 4, 5, 7, 10, and 14, or until all evidence of the bird is absent. On day 14, all birds, feathers or parts will be retrieved and properly discarded. Results of trials provide a basis for determining the search frequency necessary to ensure that birds are not scavenged before they can be detected by searchers. (see Barrios and Rodriguez 2004 and Kaheawa Wind Power 2008). In some instances, carcasses may be monitored beyond the 14 day survey duration if the information being gathered substantially informs the conclusions of the monitoring exercise.

Sampling design requires that at least 20 individual carcasses are used to examine variability in carcass retention time, evenly distributed among habitat types and seasons throughout the first year of initial study. Data will be analyzed by month, season, and according to vegetation and carcass size classifications.

Searcher Efficiency Trials (SEEF)

Searcher Efficiency (SEEF) Studies represent an important component of downed wildlife monitoring and provide an estimate of carcass detection probability. As with SEEF trials at KWP, trials will be conducted in association with the regular search effort to estimate the percentage of avian/bat fatalities that are found by searchers. As with carcass removal studies, searcher efficiency will be evaluated according to habitat and vegetation classification, location, and season. Trials will be designed to evaluate differences in carcass detection rates for different sized birds and for bats. Estimates of searcher efficiency will be used to adjust estimates of direct take by accounting for carcass detection bias.

Personnel conducting carcass searches will not be told when or where trials will be conducted. On a twice weekly basis during the monitoring period, trials consisting of 5-7 bird carcasses and/or bat surrogates per trial will be administered. Prior to a search commencing, each carcass will be placed in a random manner at selected locations that will be searched on the same day. Each trial carcass will be discreetly marked and located by GPS so it can be relocated and identified when found. If carcasses of the covered species are not available, carcasses of surrogate species will be used as previously described. The frequency of SEEF trials was chosen to provide statistical confidence in the resultant values and enable mean searcher detection probabilities to be ascertained for the project site. Data will be analyzed by month, season, and according to vegetation and carcass size classifications.

Searcher efficiency rates using Wedge-tailed Shearwaters, a close relative of comparable size and resemblance to both covered seabird species, as surrogates have ranged between 50% and 100% in 11 trials conducted between March 2007 and July 2008 with an average overall detection rate of 0.69 at KWP. Increasing the overall number and size range of surrogate specimens used in SEEF trials performed during the initial year of study will provide a better representation of variability among seasons and conditions, resulting in greater confidence in this species-specific adjustment variable.

Plot Size

Studies by Osborn et al. (2000) showed that smaller birds, as well as birds dropped from higher elevations, generally resulted in specimens landing farther from the base of the turbine on windy days. Thus the potential for wind drift, turbine size, the size, mass, and proportions of the birds being studied are all important considerations in determining the size of the search area. Based on their trials, Osborn et al. (2000) arrived at a search area that extended a minimum of 50m outward from the base of the KVS-33 turbines that were the subject of their study, which have a total structural height (support tower plus vertical rotor blade) of approximately 52m.

In their experience with numerous projects, Northwest Wildlife Consultants, Inc. (NWC), biologists have come to recommend a plot size that extends outward from the base of the turbine a distance equal to the turbine height (R. Gritzki and K. Kronner, pers. comm.) Thus for the turbines to be constructed at KWP II, which have a structural height of approximately 100m, KWP II will have circular search plots of 200m in diameter, centered on each turbine. These dimensions are reasonable given that, in addition to very few fatalities documented at KWP, none were discovered greater than 42 meters from the edge of the tower base. The average distance of bird fatalities from the turbine search plots studied at the Mars Hill Wind energy facility in Maine was 35 m (115 ft). The maximum and minimum detected distance of bird and bat fatalities from a tower was 73 m (239 ft) and 1.2 m (4 ft), and 1.5 m and 38 m, respectively (Stantec, 2008). The analysis of the distance of birds and bats from the turbines at Mars Hill included fatalities that were found scavenged and may have been moved from their original location. Nevertheless, Stantec (2008) determined that 73% of bird and 100% of bat carcasses were located by searchers at Mars Hill within 40 m of the base of turbines. The turbine maximum rotor-swept height at Mars Hill was 119 m, 19 m taller than the proposed turbines for KWP II. The circular plots at KWP II will have parallel transects that are longest in the center of each plot, closer to the turbine base, and shorter as they get farther from the center (Fig 1). Unlike the square search plots used at KWP, the circular shape and grouped arrangement of the search plots at KWP II will reduce unnecessary searching of areas outside the prescribed search area and is expected to increase efficiency.

Search Frequency

As with KWP, at this time it is anticipated that systematic foot searches will initially be conducted twice per week during the fledging periods for the two seabird species (assume eight weeks during October–December) and Nene (assume eight weeks during May-June), and at least weekly during the remainder of the survey period. Although the results of modeling do not suggest that fledgling seabird exposure is higher than during the rest of the seabird breeding season at KWP II, based on estimated passage rates, it is generally agreed that a more conservative approach is prudent during this period. Due to their large size and mass compared to seabirds and bats, Nene are not expected to be less detectable by searchers regardless of season. However, a similarly conservative approach will be implemented to account for the perceived elevated exposure of this covered species during the spring fledging period. In addition, search intervals will also reflect seasonal carcass removal rates and may be adjusted as necessary. If the minimal search interval is exceeded, KWP II will report such discrepancies to the DLNR and USFWS within one week. If the minimal search interval is exceeded more than once per season due to any reason other than health or safety, all parties will meet within one month to discuss possible adaptive management measures to adjust and correct the problem as necessary. Such occurrences will be reported in the semi-annual and annual reports.

Standardized Searches

For standard foot searches conducted by trained technicians, circular plots will be searched by walking parallel transects at regular intervals (Fig. 1). Initially, transects will be set at 6-8 meters apart in the area to be searched. A searcher will walk at a rate of approximately 40-60 meters a minute along each transect, searching on both sides out to 3-4 meters for casualties. Similar to the adaptive strategies developed at KWP, searcher speed may be adjusted by habitat (vegetation and terrain) and steepness of terrain after practice and with site familiarity. Because many of the search plots overlap with neighboring plots they form contiguous groupings of 1-5 plots. Depending upon terrain, and whether casualties are found, it should take one searcher an average of 1 hour and 20 minutes to search each plot, depending on plot grouping and configuration. All casualties will be documented on standardized field forms, located with GPS, photographed and, if a covered species, reported promptly to DLNR and USFWS in accordance with the Downed Wildlife Protocol.

Non-Standardized Searches

As encountered at KWP, there is the potential for small segments of a few turbine search plots to overlap with steep edges and portions of adjacent gulches that will make foot searches impractical. Where standard foot searches are not possible due to safety and impact avoidance considerations, these portions will be surveyed using visual aids from vantage points that provide an alternative means of detecting downed wildlife. These overlap sections represent a very small proportion of the combined search areas (ca. 7%) and occur near the edges of the turbine plot boundaries. As discussed above, few, if any, carcasses would be expected to be found in the overlap portions of the plots in most cases. To account for carcasses that might be overlooked in these overlap areas a correction factor will be applied that considers the distance from the center of the search plot to the edge of the overlap portion of the plot (Fiedler et. al. 2007). Each plot will be partitioned into 5 meter bins that radiate outward from the center. Each bin will be assigned an adjustment value based on the total adjusted carcasses estimated for each bin and the percent searchable area within the bin. For example, if 10% of observed bird and bat fatalities were found in the 15.1-20 meter annulus bin for a specific turbine and the total adjusted fatality number was 3, then 10% of 3 equals 0.3 adjusted fatalities for that annulus bin. Additionally, if 60% of the available area in that annulus was searchable, then 0.3 would be only 60% of the total number of birds or bats in that interval. Therefore, 0.3 / 0.60 = 0.5 area-corrected fatalities for that annulus. Applying this model to the overlap portions of the KWP II search plots will enable a correction to be applied to those portions of the plots that are not searchable using the standardized foot search methods. The effectiveness of this approach to correcting for unobserved carcasses in the overlap portions of the plots will be evaluated and modified as necessary in consultation with DLNR, USFWS, and the ESRC.

LONG-TERM MONITORING

Based on the outcome of the initial intensive surveys, a less labor-intensive protocol for the long-term monitoring of bird and bat fatalities at KWP II will eventually be developed. Long-term methods will be developed in consultation with DLNR, USFWS, the ESRC, and other experts and will follow an approved sampling scheme, with random sampling within each month, season, and vegetation classification and may include sampling a subset of turbines, searching smaller plots or subplots, or simply conducting less frequent searches if it is determined that scavenging rates are low. Initial surveys will take into consideration variability in vegetation and terrain features among different portions of the site to ascertain the effects of these factors on carcass detection probability and retention time.

RESULTS

The downed wildlife monitoring data will be considered together with what has been learned during three years of monitoring at KWP, combined with input and collaboration with DLNR, USFWS, and the ESRC to determine the number of individuals taken by the project for each of the four covered species. Fatalities directly observed that can be demonstrated to be unrelated to the wind project operations, through direct observations or necropsy (for example, individuals lost to predation or other natural causes), may be excluded from the take. Adjusted take calculations will be based on search-efficiency trials and scavenger trials while taking into account seasonal and vegetation-specific values. Areas which cannot be included in monitoring for health or safety reasons, in-access, or other reasons, will be accounted for by applying the appropriate corrections and in the adjusted take calculations. The resulting take determination will provide a basis for establishing the appropriate level of monitoring and mitigation for future years of operation, as approved and in consultation with DLNR and USFWS.

LITERATURE CITED

Barrios, L. and A. Rodriguez. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology 41:72-81.

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Kaheawa Wind Power. 2008b. Kaheawa Pastures Wind Energy Generation Facility, Habitat Conservation Plan: Year 2 Annual Report. First Wind, LLC, Environmental Affairs, Newton, MA. 26 pp.

Osborn, R. G., K. F. Higgins, R., E. R. Usgaard, C. D. Dieter, and R. D. Neiger. 2000. Bird mortality associated with wind turbines at the Buffalo Ridge Wind Resource Area, Minnesota. American Midland Naturalist 143:41-52.

Pennsylvania Game Commission. 2007. Protocols to Monitor Bird and Bat Mortality at Industrial Wind Turbines. Exhibit C Used in Conjunction with the Wind Energy Cooperative Agreement.

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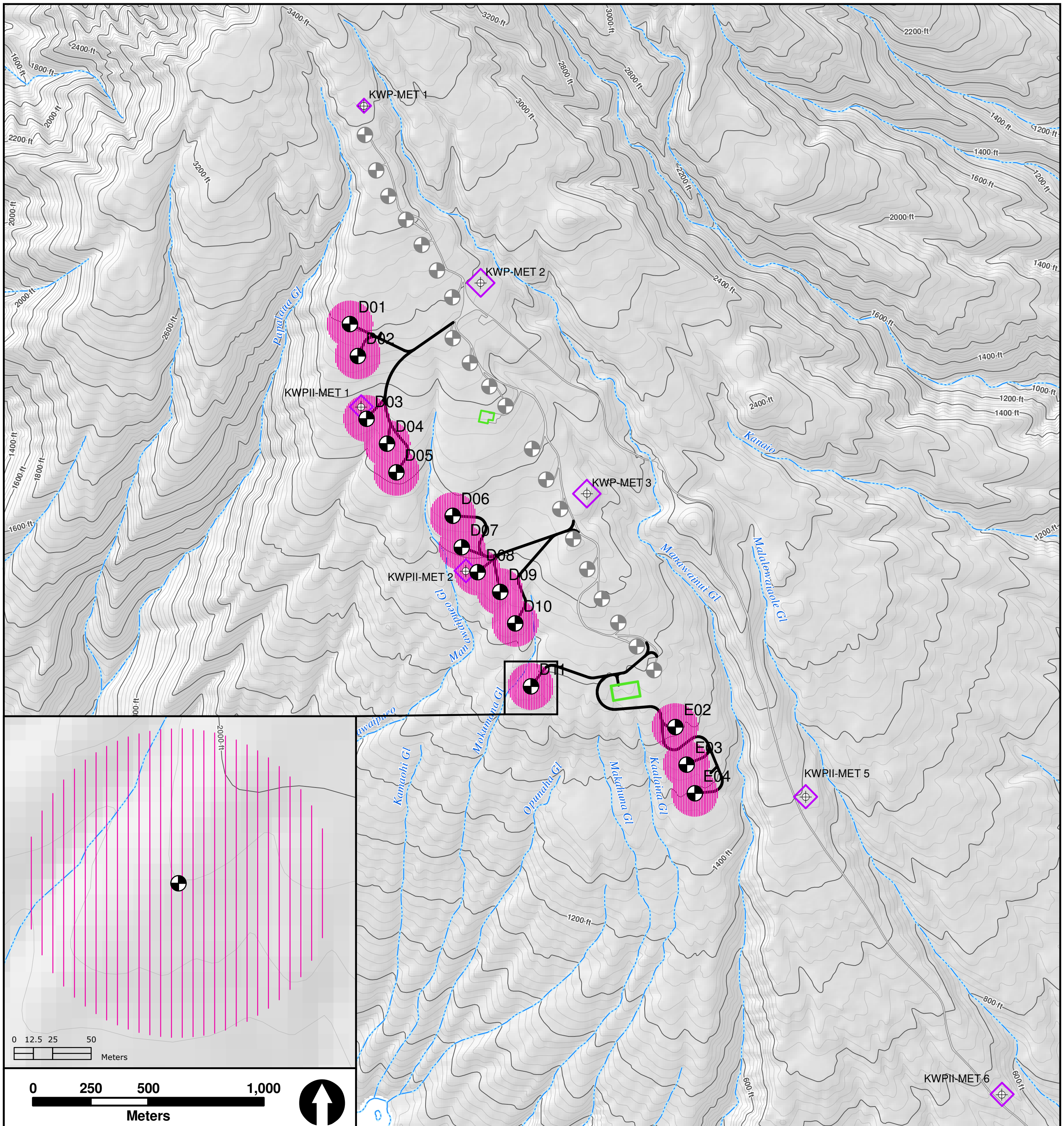

Prepared For:

Kaheawa Wind Power II

Prepared By:

SWCA
ENVIRONMENTAL CONSULTANTS

Sources: **AECOM-** (Road and Turbine Locations) **USGS-** (Topography and Streams)

Legend:

- Proposed Turbines (KWP II)
- Existing Turbines (KWP I)
- Met Towers
- 7 Meter Turbine Transects
- Met Tower Search Area
- Streams
- Substation

Contour Lines
- 200 ft Index
- 40 ft Intermediate

Figure 1:

Monitoring Transects

Kaheawa Wind Power II

Figure 1 - Monitoring Transects.mxd

Downed Wildlife Protocol

Kaheawa Wind Power II

Purpose:	To identify and document any wildlife injury or fatality incident that involves Covered Species at the Kaheawa Wind Power II site incidental to and during regular monitoring.
Applicability:	This protocol applies to all employees of Kaheawa Wind Power II and its affiliates, and extends to all consultants or other personnel who work on the site.
Covered Species:	Covered Species include the *endangered* Hawaiian Petrel, Nene, Hawaiian Hoary Bat, and the *threatened* Newell's Shearwater.
Overall Approach:	Downed wildlife may be located during the course of regular monitoring or opportunistically during routine site work. In addition to the project's monitoring program, which is a component of the project's Habitat Conservation Plan, project consultants and personnel will routinely look for and exhibit awareness of the potential to encounter downed wildlife when working at individual turbine sites, when traveling along site roads by vehicle, and when traveling the site on foot. Should any downed wildlife be found or reported, the responsible party (Senior Wildlife Biologist, Site Compliance Officer, or their official designee) shall contact Maui DLNR Forestry and Wildlife Division immediately (John Medeiros, District Wildlife Biologist) at 873-3510, to initiate response coordination. Injured wildlife may require, if instructed directly by DLNR or USFWS, that the responsible party transport the downed individual in an appropriate container (e.g. ventilated pet carrier) either to a qualified veterinarian or other facility specified by DLNR or USFWS, as described below, as soon as possible and appropriate (e.g., if the individual is alive, it shall be transported immediately). The responsible party will also complete a Downed Wildlife Monitoring Form and an official Incident Report will be submitted to DLNR and USFWS.
Facility Information:	John Medeiros, Maui DOFAW DLNR Kahului Baseyard 685 Old Haleakala Highway Kahului, Hawai`i 96732 phone: 873-3510
Contact Information:	Kaheawa Wind Power II, LLC P.O. Box 568, 3000 Honoapiilani Highway Wailuku, Hawai`i 96793 <u>contact</u>: Gregory Spencer, Senior Wildlife Biologist phone (808) 298-5097

SAMPLE

Downed Wildlife Monitoring Form
Standard Report

Monitor's Name:			Date:	
Temperature:	Wind Direction:	Wind Speed:	Precipitation:	Cloud Cover:

Turbine 1	Time Start:	Time End:
Turbine 2	Time Start:	Time End:
Turbine 3	Time Start:	Time End:
Turbine 4	Time Start:	Time End:
Turbine 5	Time Start:	Time End:
Turbine 6	Time Start:	Time End:
Turbine 7	Time Start:	Time End:
Turbine 8	Time Start:	Time End:
Turbine 9	Time Start:	Time End:
Turbine 10	Time Start:	Time End:
Turbine 11	Time Start:	Time End:
Turbine 12	Time Start:	Time End:
Turbine 13	Time Start:	Time End:
Turbine 14	Time Start:	Time End:

Other facilities or areas opportunistically surveyed:	Time Start:
	Time End:
Other facilities or areas opportunistically surveyed:	Time Start:
	Time End:

Species Detected:	Species Detected:
Comments:	Comments:
Species Detected:	Species Detected:
Comments:	Comments:

SAMPLE

Downed Wildlife Monitoring Form
Incidence Report

Turbine No.:	Species:	
Bearing from turbine:	Distance from turbine:	Location marked on map:
Condition of subject and description of injury:		
Probable cause of injury and supportive evidence:		
Evidence of scavenging:		
Action taken:		

Turbine No.:	Species:	
Bearing from turbine:	Distance from turbine:	Location marked on map:
Condition of subject and description of injury:		
Probable cause of injury and supportive evidence:		
Evidence of scavenging:		
Action taken:		

Turbine No.:	Species:	
Bearing from turbine:	Distance from turbine:	Location marked on map:
Condition of subject and description of injury:		
Probable cause of injury and supportive evidence:		
Evidence of scavenging:		
Action taken:		

SAMPLE

Appendix 3

RADAR AND VISUAL STUDIES OF SEABIRDS AT THE PROPOSED KWP II WIND ENERGY FACILITY, MAUI ISLAND, HAWAII: USE OF 2008 DATA TO MODEL ANNUAL COLLISION FATALITIES AT PROPOSED WIND TURBINES

PETER M. SANZENBACHER

BRIAN A. COOPER

PREPARED FOR

FIRST WIND
NEWTON, MASSACHUSETTS

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FOREST GROVE, OREGON

RADAR AND VISUAL STUDIES OF SEABIRDS AT THE PROPOSED KWP II WIND ENERGY FACILITY, MAUI ISLAND, HAWAII: USE OF 2008 DATA TO MODEL ANNUAL COLLISION FATALITIES AT PROPOSED WIND TURBINES

FINAL REPORT

Prepared for

First Wind

85 Wells Avenue, Suite 305

Newton, MA 02459

Prepared by

Peter M. Sanzenbacher

and

Brian A. Cooper

ABR, Inc.—Environmental Research & Services

P.O. Box 249

Forest Grove, OR 97116

January 2009

Printed on recycled paper.

EXECUTIVE SUMMARY

- We used radar and visual methods to collect data on movements of endangered Hawaiian Petrels (*Pterodroma sandwichensis*) and threatened Newell's (Townsend's) Shearwaters (*Puffinus auricularis newelli*) at the proposed Kaheawa Wind Power II (KPW II) wind energy generation facility, on Maui Island during summer and fall 2008. We conducted evening and morning surveys during 10 nights of sampling each season from 13–22 July in summer and 21–30 October in fall.
- The objectives of the study were to 1) document movement rates of Hawaiian Petrels and Newell's Shearwaters at two sampling stations with coverage of the proposed KWP II facility, (2) estimate the daily number of petrels/shearwaters that fly within areas that would be occupied by wind turbines at the proposed KWP II facility, and (3) estimate annual fatality rates of petrels/shearwaters at proposed turbines.
- We recorded 19 radar targets that fit our criteria for petrels and shearwaters during 40.6 hours of sampling in summer. Of these targets, we recorded 7 at the upper sampling station and 12 at the lower sampling station. In the fall we recorded 4 targets that fit our criteria for petrels and shearwaters during 38.9 hrs sampling. All of these targets were recorded at the lower station.
- The mean movement rate across both stations and all nights was 0.456 ± 0.15 targets/hr during summer and 0.094 ± 0.07 targets/hr during fall. Mean movement rates during summer were 0.336 ± 0.12 targets/hr at the upper station and 0.576 ± 0.16 targets/hr at the lower station. Mean movement rates during fall were 0.0 targets/hr at the upper station and 0.188 ± 0.09 targets/hr at the lower station. After adjusting our sampling results for hours of the night that we did not sample (i.e., non-peak periods), we estimated a mean movement rate across all sampling stations of 2.8 petrel-like targets/night during summer and 0.6 petrel-like targets/night during fall.
- We did not detect any petrel/shearwater targets during visual sampling, using binoculars and night-vision methodologies.
- To determine the risk of collision-caused mortality, we used petrel/shearwater movement rates observed on radar in summer and fall 2008, petrel/shearwater flight altitudes from previous studies, and dimensions and characteristics of the proposed turbines to generate an estimate of exposure risk. To this estimate of exposure, we then applied estimates of the fatality probability (i.e., the probability of collision with a portion of the turbine and dying while in the airspace occupied by the structure) and a range of estimated avoidance probabilities (i.e., the probability that a bird will detect and avoid entering the airspace containing the turbine) in order to calculate annual fatality rates that could be expected at the proposed turbines.
- We estimate that ~348 Hawaiian Petrels and ~193 Newell's Shearwaters pass over the radar sampling area annually.
- We estimated annual fatality rates at wind turbines by assuming that 90%, 95%, or 99% of all petrels/shearwaters flying near a turbine will see and avoid the structure. Based on these scenarios, annual fatality rates ranged from 0.004–0.047 Hawaiian Petrels/turbine/yr and 0.002–0.026 Newell's Shearwaters/turbine/year. Although the range of assumed avoidance rates of seabirds and met towers (90–99%) is not fully supported by empirical data at this time we speculate that avoidance rates of petrels and shearwaters at wind farm structures (e.g., wind turbines) are most likely high (>90%), based upon fatality rates at existing windfarms and avoidance behavior of petrels observed at other structures (e.g., powerlines and communication towers), and thus expect that fatality rates will be toward the low end of the range of estimates.

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ACKNOWLEDGMENTS

We thank First Wind for funding this study and also providing the ornithological radar used for sampling. We thank Greg Spencer and Dave Cowan (First Wind) for help with logistics and thank Greg Spencer, Ian Bordenave, and Bob Roy (First Wind) for their assistance with the radar and visual sampling. Makena White at Planning Solutions, Inc. (Honolulu, Hawaii) provided GIS data for study figures. At ABR, Dorte Dissing produced study figures and Pam Odom assisted with report production.

INTRODUCTION

First Wind, formerly UPC Wind Management, LLC, operates the 30 MW Kaheawa Pastures Wind Energy Generation Facility, referred to as Kaheawa Wind Power (KWP I), on the island of Maui (Figure 1). A new wind project adjacent to the existing facility will be developed by First Wind and operated as Kaheawa Wind Power II (KWP II). Two federally-listed seabird species occur on Maui: the endangered Hawaiian Petrel (*Pterodroma sandwichensis*; Hawaiian name: ’Ua’u) and the threatened Newell’s (Townsend’s) Shearwater (*Puffinus auricularis newelli*; Hawaiian name: ’A’o). Ornithological radar and night-vision techniques have been shown to be successful in assessing numbers and movement rates of petrels and shearwaters on the Hawaiian Islands (e.g., Kaua’i [Cooper and Day 1995, 1998; Day and Cooper 1995, Day et al. 2003b], Maui [Cooper and Day 2003], Moloka’i [Day and Cooper 2002] and Hawai’i [Reynolds et al. 1997, Day et al. 2003a]). Previous radar and visual studies documented the presence of petrel/ shearwater targets in the vicinity of the KWP I project site, including visual observations of Hawaiian Petrels (Day and Cooper 1999, Cooper and Day 2004a). These data were used to model the potential number of annual fatalities at the KWP I development (Cooper and Day 2004b).

The currently operational KWP I wind energy facility consists of an articulated row of 20 1.5-MW turbines (GE 1.5se) with a hub height of ~55 m and rotor diameter of 70.5 m, plus one 30-m-high, guyed NRG monopole meteorological (met) tower and two 55-m-high, guyed lattice-style met towers (Figure 2). The proposed KWP II project would consist of ~14 additional 1.5-MW turbines (GE 1.5se), each with a hub height of ~65 m and a rotor diameter of 70.5 m, plus four 50-m-high monopole met towers.

ABR conducted additional radar and visual studies on Maui in July and October 2008 with a

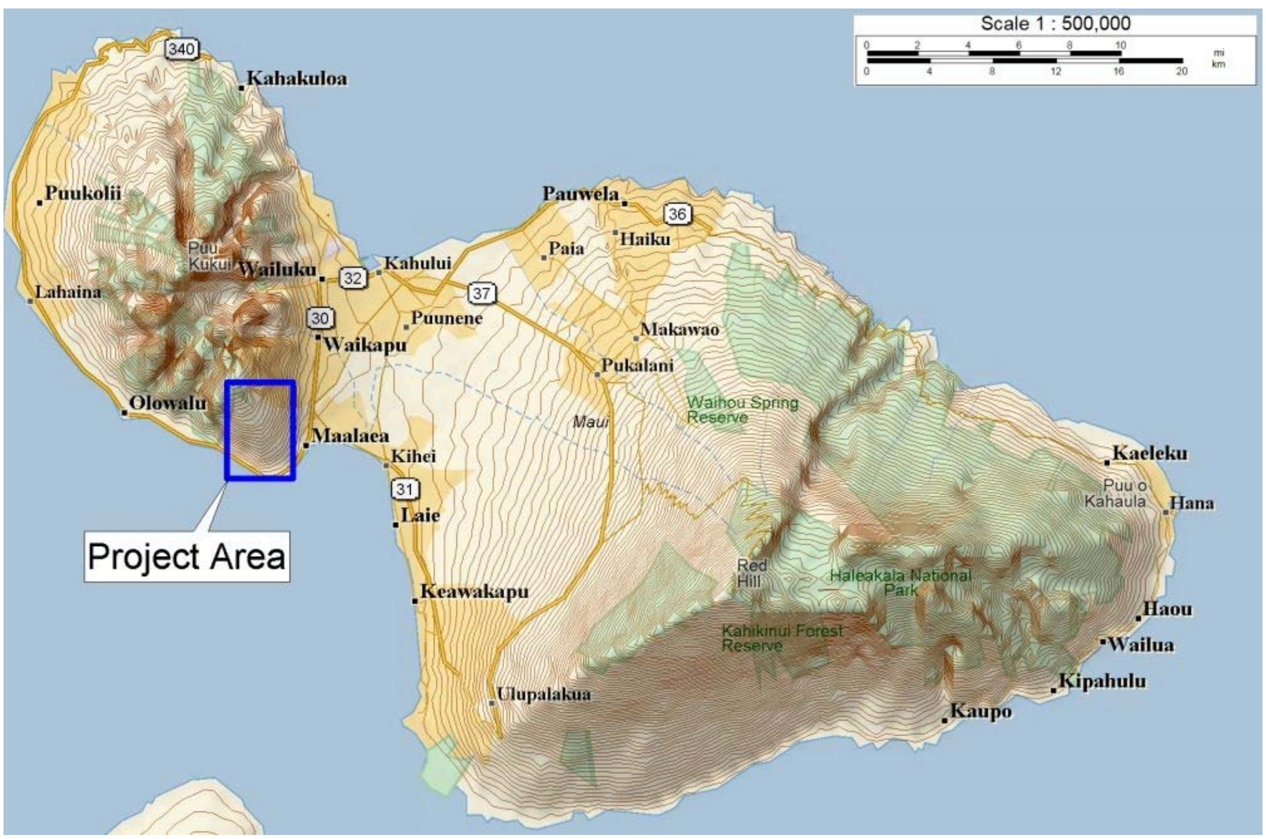

Figure 1. Maui Island, Hawaii, with approximate location of the Kaheawa Pastures Wind Energy Facilities (KWP I and KWP II).

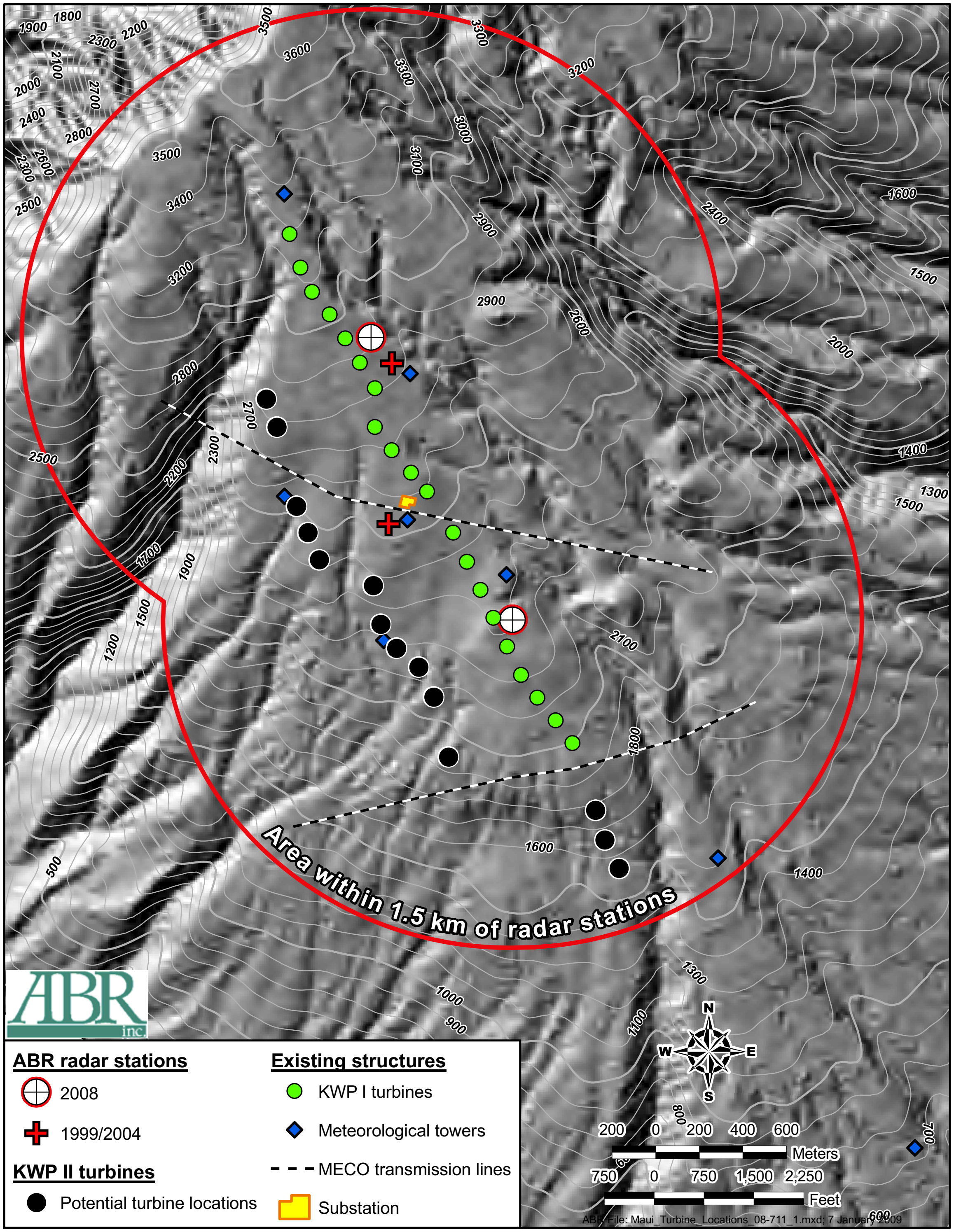

Figure 2. Location of 2008 radar sampling stations relative to previous radar sampling stations (Day and Cooper 1999, Cooper and Day 2004a) and areas under consideration for siting of proposed turbine strings at the KWP II wind energy facility, Maui, Hawaii.

specific focus on areas proposed for the KWP II development. In this report we present a summary of results from these studies including (1) movement rates of Hawaiian Petrels and Newell's Shearwaters at two sampling stations with coverage of KWP I and also areas proposed for the KWP II development, (2) estimates of the daily number of petrels that fly within the areas occupied by turbines proposed for the KWP II project, and (3) estimates of annual fatality rates of petrels at the proposed turbines.

BACKGROUND

Two seabird species that are protected under the Endangered Species Act (ESA) are likely and/or known to occur in the KWP II project area: the endangered Hawaiian Petrel and the threatened Newell's (Townsend's) Shearwater. The Hawaiian Petrel ('Ua'u) and the Newell's Shearwater ('A'o) are forms of tropical Pacific species that nest only on the Hawaiian Islands (American Ornithologists' Union 1998). Both species are Hawaiian endemics whose populations have declined significantly in historical times: they formerly nested widely over all of the Main Islands but now are restricted in most cases to scattered colonies in more inaccessible locations (Ainley et al. 1997b, Simons and Hodges 1998). The one exception is Kaua'i Island; there, colonies still are widespread and populations are substantial in size. Of note, Kaua'i (along with Lana'i) also has no introduced Indian Mongooses (*Herpestes auropunctatus*) which prey on these seabirds. Because of their low overall population numbers and restricted breeding distributions, both of these species are protected under the Endangered Species Act.

The Hawaiian Petrel is known to nest primarily on Maui (Richardson and Woodside 1954, Banko 1980a; Simons 1984, 1985; Simons and Hodges 1998, Cooper and Day 2003), Kaua'i (Telfer et al. 1987, Gon 1988, Day and Cooper 1995; Ainley et al. 1995, 1997a, 1997b; Day et al. 2003a), Hawai'i (Banko 1980a, Conant 1980, Hu et al. 2001, Day et al. 2003a), Lana'i (Shallenberger 1974; Hirai 1978a, 1978b; Conant 1980; G. Spencer and J. Penniman, pers. comm.), and Moloka'i (Simons and Hodges 1998, Day and Cooper 2002). On Maui, these petrels are known to nest on Haleakala Crater (Brandt et al. 1995, Simons and Hodges 1998) and recent observations of birds calling and exhibiting aerial displays consistent with breeding behavior indicate the presence of Hawaiian Petrel nesting colonies in West Maui despite the minimal historical evidence and introduction of Indian Mongoose on Maui. For example, on 16 June 1999, a Hawaiian Petrel was heard calling from a bed of uluhe ferns (*Dicranopteris linearis*) at 3,300 ft elevation in the Kapunakea Preserve, which lies on the northwestern slope of the West Maui Natural Area Reserve (A. Lyons, *fide* C. Bailey). Further, Cooper and Day (2003) observed Hawaiian Petrels flying inland over the northern coast toward West Maui Mountain. In addition, recent observations of consistent calling from a single location suggests that there is another small colony of Hawaiian Petrels in the west Maui Mountains ~14 km north of the KWP project areas (G. Spencer, First Wind, pers. comm.). Daily movement rates of Hawaiian Petrels near KWP I and II (i.e., on the southern slope of West Maui Mountain) are much lower than those over the eastern and northern sides of Maui (Cooper and Day 2003).

Newell's Shearwaters nest on several of the main Hawaiian Islands, with the largest numbers clearly occurring on Kaua'i (Telfer et al. 1987, Day and Cooper 1995, Ainley et al. 1995, 1997b, Day et al. 2003b). These birds also nest on Hawai'i (Reynolds and Richotte 1997, Reynolds et al. 1997, Day et al. 2003a), almost certainly nest on Moloka'i (Pratt 1988, Day and Cooper 2002), and may still nest on Oahu (Sincock and Swedberg 1969, Banko 1980b, Conant 1980, Pyle 1983; but see Ainley et al. 1997b). On Maui, recent auditory observations suggest that a small colony of Newell's Shearwaters is present in the west Maui Mountains ~14 km north of the KWP project areas (G. Spencer, First Wind, pers. comm.). Newell's Shearwaters typically nest on steep slopes that are vegetated by uluhe fern (*Dicranopteris linearis*) undergrowth and scattered ohia trees (*Metrosideros polymorpha*).

There is interest in studying these two species because of concerns regarding collisions with structures such as met towers and turbines. To date, there is documented mortality of only one Hawaiian Petrel (at a wind turbine; G. Spencer, First Wind, pers. comm.) and zero Newell's

Shearwaters at wind energy facilities within the Hawaiian Islands. Note, however, that fatality studies have been conducted for three years (33 months) at one wind energy location in the Hawaiian Islands (Kaheawa Wind Power, Maui), plus a three-month-long fatality study of six met towers at the same site prior to operation. Nevertheless, there have not been enough studies of adequate duration to definitively answer the question on whether these species are prone to collisions at these structures. Of note, there has been petrel and shearwater mortality because of collisions with other human-made objects (e.g., transmission lines) on Kaua'i (Telfer et al. 1987, Cooper and Day 1998, Podolsky et al. 1998) and Maui (Hodges 1992). In addition, there have been collision-caused fatalities of other seabirds at other Pacific Islands. For example, nearly 2 million seabirds comprising 18 different species nest on Midway Atoll (USFWS 2008) and collisions with antenna wires and guyed lattice towers sited near these seabird nesting colonies with high densities of birds has resulted in fatalities of Laysan Albatrosses (*Diomedea immutabilis*), Black-footed Albatrosses (*Diomedea nigripes*), Wedge-tailed Shearwaters (*Puffinus pacificus*), Bonin Petrels (*Pterodroma leucoptera*), Red-tailed Tropicbirds (*Phaethon rubricauda*), Sooty Terns (*Sterna fuscata*), and a Bulwer's Petrel (*Bulweria bulwerii*, Fisher 1966).

STUDY AREA

The operational KWP I windfarm and proposed KWP II expansion are located on the southern slope of West Maui Mountain, in an area called Kaheawa Pastures (Figure 1). These sites lie on a moderately sloping portion of West Maui Mountain, ~6 km inland from McGregor Point. Vegetation at the site consists of grasslands at lower elevations and a mixture of grasslands and scattered shrubs at moderate to higher elevations. Shrubs and scattered trees line the nearby gulches and directly above the site, shrubs dominate, with native ohia trees (*Metrosideros polymorpha*) and uluhe ferns becoming more common. Although the site consists of a dry Mediterranean habitat, vegetation becomes much wetter upland, toward the summit of West Maui Mountain. Presumably, vegetation communities also are dominated by native species in these higher, wetter areas. These more upland habitats may provide suitable nesting habitat for Newell's Shearwaters, based on our experience on Kaua'i and other sites. In addition to the vegetation, the steepness of higher elevations on West Maui Mountain also suggests suitable nesting habitat exists for Hawaiian Petrels, as it does on Haleakala (Brandt et al. 1995), Kaua'i (Telfer, pers. comm.), and Lana'i (Hirai 1978b).

In previous studies at the site (Day and Cooper 1999, Cooper and Day 2004a) sampling was conducted at the same two stations, however, for the current studies we established two new sampling stations with a focus on providing maximum radar coverage of potential siting areas for the proposed KWP II development. These areas were situated slightly to the east, west, and south of the existing KWP I turbine string; however, note that currently the areas under consideration for siting of turbines is situated to the west and south of the existing KWP I turbine string (Figure 2). Similar to previous studies one station was on the northern (upper) end of the study area (20° 49'14 N, 156° 33'10 W; ~899 m above sea level; Datum = WGS84); and one was on the southern (lower) end of the study area (20° 48'32" N, 56° 32'49" W; ~725 m above sea level).

METHODS

We used marine radar and visual equipment to collect data on the movements, flight behaviors, and flight altitudes of petrels and shearwaters at two sampling stations during summer (13–22 July) and fall (21–30 October) 2008 (Table 1). We attempted to sample an equal number of days at both the upper station and lower station during each season and the daily sampling effort consisted of 3 h/evening (summer = 1900–2200 hrs, fall = 1800–2100) and 2 h/morning (summer = 0400–0600 hrs, fall = 0430–0630). These sampling periods were selected to correspond to the evening and morning peaks of movement of petrels and shearwaters, as described near breeding colonies on Kaua'i (Day and Cooper 1995). During sampling, we collected radar and visual data concurrently so the radar operator could help the visual observer locate birds for species identification and data collection. In return, the visual observer provided information to the radar

Table 1. Sampling dates, number of landward and seaward seabird radar targets, and number of audio-visual and acoustic observations of species of interest, Maui Island, Hawaii, July and October 2008.

			Number of radar targets			Number of audio-visual detections[1]	
Date	Station	Period	Landward[2]	Seaward[2]	Total	Visual	Acoustic
13 July	Upper	Eve	0	1	1	0	0
		Morn	0	1	1	0	0
14 July	Upper	Eve	0	0	0	1 SEOW	0
		Morn	0	0	0	0	0
15 July	Upper	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
16 July	Upper	Eve	1	2	3	0	0
		Morn	0	0	0	0	0
17 July	Upper	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
18 July	Lower	Eve	0	2	2	0	0
		Morn	0	0	0	0	0
19 July	Lower	Eve	0	5	5	0	0
		Morn	0	0	0	0	0
20 July	Lower	Eve	1	1	2	0	0
		Morn	0	0	0	0	0
21 July	Lower	Eve	0	2	2	0	0
		Morn	0	0	0	0	0
22 July	Lower	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
21 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	2 SEOW	0
22 Oct	Upper	Eve[3]	-	-	-	-	-
		Morn	0	0	0	0	0
23 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
24 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
25 Oct	Lower	Eve	0	0	0	0	0
		Morn	0	1	1	0	0
26 Oct	Lower	Eve	1	0	1	1 SEOW	0
		Morn	0	1	1	2 NENE	0
27 Oct	Lower	Eve	0	0	0	1 HOBA, 1 PGPL	0
		Morn	0	0	0	0	0
28 Oct	Lower	Eve	0	0	0	1 HOBA	0
		Morn	0	1	1	0	0
29 Oct	Lower	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
30 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0

[1] Species codes refer to HOBA = Hoary Bat (*Lasiuris cinereus semotus*), NENE = Hawaiian Nene (*Branta sandvicensis*), PGPL = Pacific Golden Plover (*Pluvialis fulva*), SEOW = Short-eared Owl (*Asio flammeus sandwichensis*).
[2] Flight direction categories for landward and seaward categories included all birds flying toward and away, respectively, from either the colonies located on the opposite end of west Maui to the north of the study site or colonies on Haleakala.
[3] No sampling conducted due to logistical issues.

operator on the identity and flight altitude of individual targets (whenever possible). For the purpose of recording data, a calendar day began at 0700 and ended at 0659 the following morning; that way, an evening and the following morning were classified as occurring on the same day.

The ornithological radar used in this study was a Furuno (Model FCR-1510) X-band radar transmitting at 9.410 GHz through a slotted wave guide with a peak power output of 12 kW; a similar radar unit is described in Cooper et al. (1991) and Mabee et al. (2006). The antenna face was tilted upward by ~10–15°, and we operated the radar at a range setting of 1.5 km and a pulse-length of 0.07 µsec.

Issues associated with radar sampling include ground clutter and shadow zones. Whenever energy is reflected from the ground, surrounding vegetation, and other objects around the radar unit, a ground-clutter echo appears on the radar's display screen that can obscure targets of interest (i.e., birds). Shadow zones are areas of the screen where birds can fly at an altitude that would potentially put them behind a hill or row of vegetation where they could not be detected because the radar operates only on line-of-sight. We attempted to minimize ground clutter and shadow zones during the selection of radar sampling stations and various structures and landscape features visible on radar indicated that our sampling stations provided good coverage of the areas of interest.

We sampled for six 25-min sessions during each evening period and for four 25-min sessions each morning (Table 1). We conducted an additional sampling session prior to official start time on some mornings in summer and fall, but the lack of targets suggested that our main sampling times were sufficient to encompass the morning period of peak petrel/shearwater activity. Each 25-min sampling session was separated by a 5-min break for collecting weather data. To help eliminate non-target species we collected data only for those targets that met a suite of selection criteria, following methods developed by Day and Cooper (1995), that included appropriate flight characteristics and flight speeds (≥30 mi/h [≥50 km/h]). We also removed radar targets identified by visual observers as other bird species.

We conducted visual sampling for birds and bats concurrently with the radar sampling to help identify targets observed on radar and to obtain flight-altitude information. During this sampling, we used 10X binoculars during crepuscular periods and Generation 3 night-vision goggles (Model ATN-PVS7; American Technologies Network Corporation, San Francisco, CA) during nocturnal periods. The magnification of the night-vision goggles was 1×, and their performance was enhanced with the use of a 3-million-Cp floodlight that was fitted with an IR filter to avoid blinding and/or attracting birds. Visual observations were conducted within 25 m of the radar to facilitate coordination between observers and we also listened for any petrel/shearwater vocalizations.

Before each 25-min sampling session, we also collected environmental and weather data, including:

- wind speed (to the nearest 1.6 km/h [1 mi/h]);
- wind direction (to the nearest 1°);
- percent cloud cover (to the nearest 5%);
- cloud ceiling height, in meters above ground level (agl; in several height categories);
- visibility (maximal distance we could see, in categories);
- light condition (daylight, crepuscular, or nocturnal, and with or without precipitation)
- precipitation type; and
- moon phase/position (lunar phase and whether the moon was above or below the horizon in the night sky).

For each appropriate radar target, we recorded the following data:

- species (if identified by visual observer);
- number of birds (if identified by visual observer);
- time;
- direction of flight (to the nearest 1°);
- cardinal transect crossed (000°, 090°, 180°, or 270°);

- tangential range (the minimal distance to the target when it passed closest to the radar; used in reconstructing actual flight paths, if necessary);
- flight behavior (straight, erratic, circling);
- velocity (to the nearest 5 mi/h [8 km/h]); and
- flight altitude (meters agl, if identified by visual observer).

For each bird (or bat) seen during night-vision sampling, we recorded:

- time;
- species (to the lowest practical taxonomic unit [e.g., Hawaiian Petrel, unidentified petrel/shearwater]);
- number of individuals composing each target;
- ordinal flight direction (000°, 045°, 090°, 135°, 180°, 225°, 270°, 315°); and
- flight altitude (meters agl).

For any birds heard but not observed, we recorded species, number of calls, direction of calls, and approximate distance.

DATA ANALYSIS

We entered all radar and visual data into Microsoft Excel databases. Data files were checked visually for errors after each night's sampling, then were checked electronically for irregularities at the end of the field season, prior to data analyses. All data summaries and analyses were conducted with SPSS 14.0 statistical software (SPSS 2005). Prior to analyses, radar data were filtered to remove non-target species and only known petrel/shearwater targets or unknown targets with appropriate characteristics (i.e., target size, flight characteristics, and airspeeds ≥30 mi/h) were included in data analyses. Airspeeds were calculated by correcting observed target flight speeds (groundspeeds) for speed and relative direction of wind, as measured each half hour at the radar station (Mabee et al. 2006).

We tabulated counts of numbers of radar targets recorded during each sampling session, then converted those counts to estimates of movement rates of birds (radar targets/h), based on the number of minutes sampled. Some sampling time was lost to rain or other factors; so we standardized estimates by actual sampling effort. We used all of the estimated movement rates across sampling sessions at a station to calculate the mean ± 1 standard error (SE) nightly movement rate by station and also lumped data across stations and nights to derive an overall hourly movement rate for the study.

We also classified general flight directions of each radar target as landward or seaward, and summarized those directional categories by station, date, and time period. To categorize the general flight direction of each target, we defined a landward flight as a radar target flying toward the west Maui Mountains or Haleakala on east Maui. Targets flying in the opposite directions were considered seaward targets.

MODELING FATALITY RATES

The risk-assessment technique that we have developed involves the use of radar data for estimating the fatality rates for petrels and shearwaters near structures in the Hawaiian Islands. This modeling technique uses the radar data on seasonal movement rates to estimate numbers of birds flying over the area of interest (sampling stations) across a 210-d year (for Newell's Shearwater) or 255-d year (for Hawaiian Petrels) when breeding birds are present on the island. The model then uses information on the physical characteristics of the structures (e.g., wind turbines) themselves to estimate horizontal and vertical interaction probabilities and combines these interaction probabilities with the movement rates to generate exposure rates (Figure 3). These exposure rates represent the estimated numbers of petrels/shearwaters that pass within the airspace occupied by a turbine at each site each year. We then combine these exposure rates with (1) the probability that an interaction results in fatality, and (2) the probability that birds detect turbines and avoid interactions, to estimate fatality rates.

We calculate an exposure rate by multiplying the seabird movement rate observed on radar by horizontal- and vertical-interaction probabilities. The movement rate is an estimate of the average number of birds passing in the vicinity of the

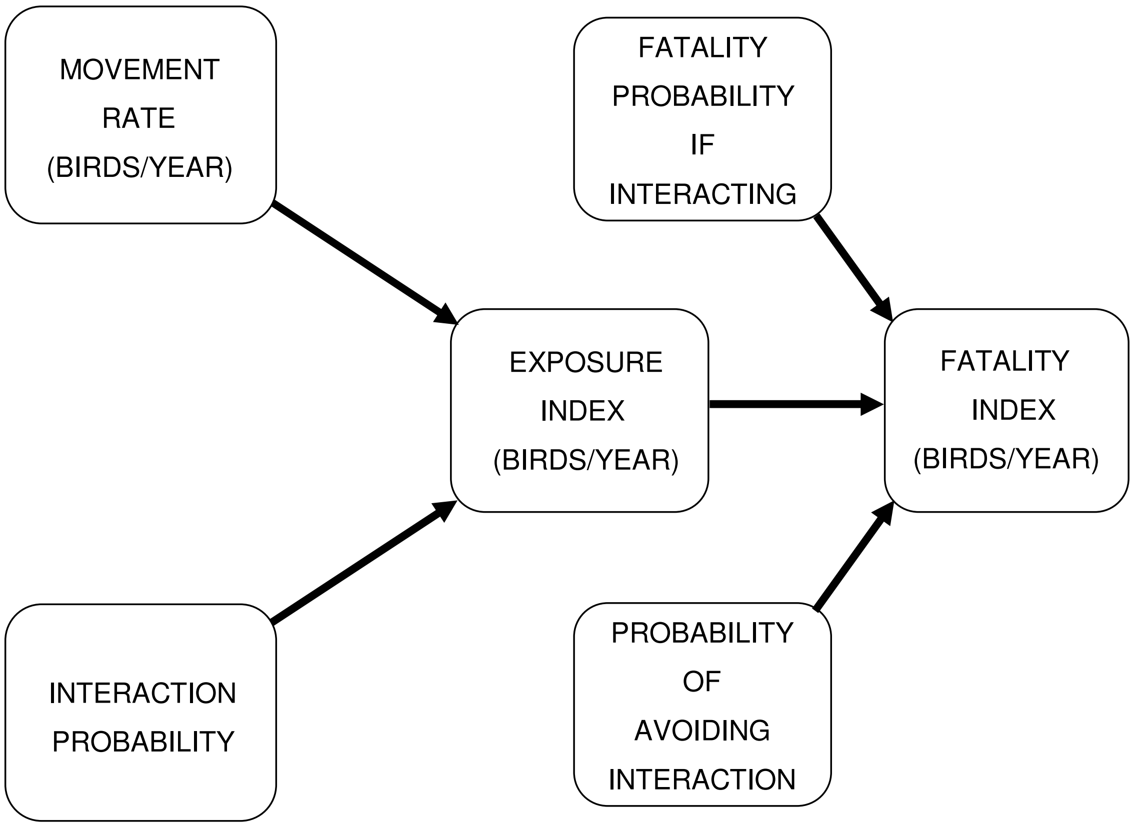

Figure 3. Major variables used in estimating possible fatalities of seabirds (Hawaiian Petrels and Newell's Shearwaters) at wind turbines at the proposed KWP II wind energy facility, Maui, Hawaii. See Table 2 for details on calculations.

proposed turbines in a day, as indicated by numbers of targets on the radar screen and the mean flock size/target. It is generated from the radar data by: (1) multiplying the average movement rates by 5.5 h to estimate the number of targets moving over the radar site in the first 3 h and last 2.5 h of the night (i.e., during the peak movement periods of petrel/shearwaters); (2) adjusting the sum of those evening and morning counts to account for the estimated percentage of movement that occurs during the middle of the night; and (3) multiplying that total number of targets/night by the mean number of seabirds/target to generate an estimate of the number of petrel/shearwaters passing in the vicinity of the proposed turbines during an average day.

We used the radar-based movement data from our current study at the proposed KWP II development to estimate seabird movement-rates in both summer and fall and assumed that those rates represented average rates observed in an average year. We used data from all-night sampling sessions on Kaua'i (Day and Cooper 1995) to estimate movement rates occurring during the hours between our evening and morning sampling periods. These data suggested that an additional 12.6% of the total combined evening landward movements and seaward morning movements occurred between the evening and morning peak movement periods (Day and Cooper, unpubl. data). We also corrected the number of targets for flock size: mean flock sizes of petrels and shearwaters combined in Hawai'i are 1.05 ± SE 0.01 birds/flock (*n* = 2,062 flocks; Day and Cooper, unpubl. data). In addition, we used the timing of inland flights at the nearby Ukumehame site from Cooper and Day (2003) to correct for proportions of targets that were Hawaiian Petrels and those that were Newell's Shearwaters; those data suggested that 60% of the targets were Hawaiian Petrels and 40% of the targets were Newell's Shearwaters (see below).

The number of petrels visiting breeding colonies tends to decline from summer to fall because attendance at colonies by nonbreeders and failed breeders declines as chick-rearing progresses (Serventy et al. 1971, Warham 1990, Ainley et al. 1997b, Simons and Hodges 1998). Thus, we split the 255-d breeding season for Hawaiian Petrels (Simons and Hodges 1998) and 210-d breeding season for Newell's Shearwaters (Ainley et al. 1997b) into a spring/summer period (i.e., 180 days and 150 days for petrels and shearwaters, respectively) and a fall period (i.e., 75 days and 60 days for petrels and shearwaters, respectively). We corrected the seasonal estimates of nightly movement rates by the numbers of days for the spring/summer and fall seasons to generate estimates of movements for each season and species. We assume that the sum of these two estimates represents estimated movement rates for an entire breeding season (i.e., an average year).

Because the resulting estimate of the number of birds/yr is not an integer, we then round it upward to the next whole number to generate an estimate of the average number of birds passing within 1.5 km of the radar site during a year. This rounding technique results in slightly-inflated fatality estimates, but we choose to take a conservative approach in these studies associated with endangered species.

INTERACTION PROBABILITIES

HORIZONTAL

Interaction probabilities consist of horizontal and vertical components. The horizontal-interaction probability is the probability that a bird seen on radar will pass through or over the airspace occupied by a proposed turbine located somewhere on the radar screen. This probability is calculated from information on the two-dimensional area (side view) of the turbine and the two-dimensional area sampled by the radar screen to determine the interaction probability. Two calculations of area were made for turbines because of the large differences in area of the structure that depended on the orientation of the blades relative to the flight path of an approaching bird: a minimal area occupied by each turbine if a bird approaches it from the side (i.e., side profile) and a maximal area occupied by each turbine if a bird approaches it from the front (i.e., front profile, including the rotor-swept area). The ensuing ratio of cross-sectional area of the turbine to the cross-sectional area sampled by the radar (1.5 km) indicates the probability of interacting with (i.e., flying over or through the airspace occupied by) the turbine.

VERTICAL

The vertical-interaction probability is the probability that a bird seen on radar will be flying at an altitude low enough that it might pass through the airspace occupied by a proposed turbine located somewhere on the radar screen. This probability is calculated from data on flight altitudes and from information on the proposed turbine heights. We used data from throughout the Hawaiian Islands (*n* = 2,010 birds; Cooper and Day, unpubl. data) to calculate the percentage of petrels/shearwaters with flight altitudes at or below the maximal height of the turbines (i.e., 51.0% ≤100 m). We would have preferred to use flight-altitude data from the project area for the flight-altitude computations, but adequate sample sizes do not currently exist to do so.

FATALITY RATES

The annual estimated fatality rate is calculated as the product of: (1) the exposure rate (i.e., the number of birds that might fly within the airspace occupied by a turbine); (2) the fatality probability (i.e., the probability of collision with a portion of the turbine and dying while in the airspace occupied by the structure); and (3) the avoidance probability (i.e., the probability that a bird will detect and avoid entering the airspace containing the turbine; Figure 3). The annual fatality rate is generated as an estimate of the number of birds killed/yr as a result of collisions with the turbine, based on a 255-d breeding season for Hawaiian

Petrels (Simons and Hodges 1998) and a 210-d breeding season for Newell's Shearwaters (Ainley et al. 1997b).

FATALITY PROBABILITY

The estimate of the fatality-probability portion of the fatality rate formula is derived as the product of: (1) the probability of dying if a bird collides with a turbine; and (2) the probability of colliding with a turbine if the bird enters the airspace occupied by the structure (i.e., are there gaps big enough for birds to fly through the structure without hitting any part of it). Because any collision with a wind turbine falls under the ESA definition of "take" we used an estimate of 100% for the first fatality-probability parameter. Note that the actual probability of fatality resulting from a collision is less than 100% because of the potential for a bird to hit a turbine component and not die (e.g., a bird could brush a wingtip but avoid injury/death). For the second probability (i.e., striking the structure) a bird approaching a wind turbine from the side has essentially a 100% probability of getting hit by a blade; in contrast, a bird approaching from the back or front of a turbine may pass through the rotor-swept area without colliding with a blade. We calculated the probability of collision for the "frontal" bird approach based upon the length of a petrel (43 cm; Simons and Hodges 1998); the average groundspeed of petrels on Maui (mean velocity = 42.5 mi/h; n = 347 probable petrel targets; Cooper and Day, unpubl. data) and the time that it would take a 43-cm-long petrel to travel completely through a 2-m-wide turbine blade spinning at its maximal rotor speed (22 revolutions/min); also see Tucker (1996). These calculations indicated that 19.5% of the disk of the rotor-swept area would be occupied by a blade sometime during the length of time (i.e., 0.13 sec) that it would take a petrel to fly completely past a rotor blade (i.e., to fly 2.43 m).

AVOIDANCE PROBABILITY

The final parameter is the avoidance probability, which is the probability that a bird will see the turbine and change flight direction, flight altitude, or both so that it completely avoids flying through the space occupied by a turbine. Because avoidance probabilities are largely unknown, we present fatality estimates for a range of probabilities of collision avoidance by these birds by assuming that 90%, 95%, or 99% of all petrels or shearwaters flying near a turbine will see and avoid it. See discussion for explanation of avoidance rates used.

RESULTS

MOVEMENT RATES

We recorded 19 radar targets during summer 2008 (40.6 hrs sampling) and 4 radar targets during fall 2008 (38.9 hrs sampling) that fit our criteria for petrels and shearwaters. During summer we detected 7 of these targets at the upper station and 12 at the lower station and in the fall we detected all 4 targets at the lower station (Table 1). In the summer movement rates at both stations tended to be higher in the evening than in the morning; only one target out of the 19 was observed during the morning sampling period. In contrast, during the fall movement rates were higher in the morning; only one target out of four was observed during the evening sampling period. Mean movement rates during summer were 0.336 ± 0.12 targets/hr at the upper station and 0.576 ± 0.16 targets/hr at the lower station. Mean movement rates during fall were 0.0 targets/hr at the upper station and 0.188 ± 0.09 targets/hr at the lower station. The mean movement rate across both stations and all days was 0.456 ± 0.15 targets/hr in the summer and 0.094 ± 0.07 targets/hr in the fall. After adjusting our sampling results for hours of the night that we did not sample (i.e., non-peak periods), we estimated a mean movement rate across all sampling stations of 2.8 petrel-like targets/night during summer and 0.6 petrel-like targets/night during fall (Table 2). We did not detect any petrel/shearwater targets during visual sampling.

EXPOSURE RATES

The exposure rate is calculated as the product of three variables: annual movement rate, horizontal-interaction probability, and vertical-interaction probability. As such, it is an estimate of the number of birds flying in the vicinity of the turbine (i.e., crossing the radar screen) that could fly in a horizontal location and at a low-enough altitude that they could interact with a turbine. Based on our 2008 movement rate data, we

Table 2. Estimated average exposure rates and fatality rates of Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at GE 1.5se wind turbines at the proposed KWP II wind-energy site, Maui, Hawaii, based on radar data collected in summer (July) and fall (October) 2008. Values of particular importance are in boxes.

	HAPE		NESH	
Variable/parameter for GE 1.5 MW 1.5se Turbine	Minimum	Maximum	Minimum	Maximum
MOVEMENT RATE (MVR)				
A) Mean movement rate (targets/h)				
a1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.456	0.456	0.456	0.456
a2) Mean rate during nightly peak movement periods in fall based on October 2008 data (targets/h)	0.094	0.094	0.094	0.094
B) Number of hours of evening and morning peak period sampling	5.5	5.5	5.5	5.5
C) Mean number of targets during evening and morning peak movement periods				
c1) Spring/summer (a2*B)	2.508	2.508	2.508	2.508
c2) Fall (a1 * B)	0.516	0.516	0.516	0.516
D) Mean proportion of birds moving during off-peak h of night	0.126	0.126	0.126	0.126
E) Seasonal movement rate (targets/night) = ((C*D)+ C)				
e1) Spring/summer	2.8	2.8	2.8	2.8
e2) Fall	0.6	0.6	0.6	0.6
F) Mean number of birds/target	1.05	1.05	1.05	1.05
G) Estimated proportion of each species	0.60	0.60	0.40	0.40
H) Daily movement rate (birds/day =E*F*G)				
h1) Spring/summer	1.78	1.78	1.19	1.19
h2) Fall	0.37	0.37	0.37	0.37
I) Fatality domain (days/year)				
i1) Spring/summer	180	180	150	150
i2) Fall	75	75	60	60
J) Annual movement rate (birds/year; = ((h1*i1) + (h2*i2)), rounded to next whole number)	$\boxed{348}$	$\boxed{348}$	$\boxed{193}$	$\boxed{193}$

Table 2. Continued.

Variable/parameter for GE 1.5 MW 1.5se Turbine	HAPE Minimum	HAPE Maximum	NESH Minimum	NESH Maximum
HORIZONTAL INTERACTION PROBABILITY (IPH)				
K) Turbine height (m)	100	100	100	100
L) Blade radius (m)	35.25	35.25	35.25	35.25
M) Height below blade (m)	29.5	29.5	29.5	29.5
N) Front to back width (m)	6	6	6	6
O) Min side profile area (m^2) = (K*N)	600		600	
P) Max front profile area (m^2) = (M*N) + (π x L^2)		4081		4081
Q) Cross-sectional sampling area of radar at or below 100 m turbine height (= 3000 m * 100 m = 300,000 m^2)	300000.00	300000.00	300000.00	300000.00
R) Minimal horizontal interaction probability (= O/Q)	0.002000		0.002000	
S) Maximal horizontal interaction probability (= P/Q)		0.01360211		0.01360211
VERTICAL INTERACTION PROBABILITY (IPV)				
T) Proportion of petrels flying ≤ turbine height)	0.51	0.51	0.51	0.51
EXPOSURE RATE (ER = MVR*IPH*IPV)				
U) Daily exposure rate (birds/turbine/day = H*(R or S)*T				
o1) Spring/summer	0.00181471	0.01234193	0.00120981	0.00822795
o2) Fall	0.00037329	0.00253876	0.00024886	0.00169250
V) Annual exposure rate (birds/turbine/year = J*(R or S)*T	0.35496000	2.41410328	0.19686000	1.33885613
FATALITY PROBABILITY (MP)				
W) Probability of striking turbine if in airspace on a side approach	1.00	1.00	1.00	1.00
X) Probability of striking turbine if in airspace on frontal approach	0.20	0.20	0.20	0.20
Y) Probability of fatality if striking turbine[1]	1.00	1.00	1.00	1.00
Z1) Probability of fatality if an interaction on side approach (= W*Y)	1.00		1.00	
Z2) Probability of fatality if an interaction on frontal approach (= X*Y)		0.195		0.195
FATALITY RATE (= ER*MP)				
Annual fatality rate with 90% exhibiting collision avoidance (birds/turbine/year = V*Z*0.10)	0.03550	0.04708	0.01969	0.02611
Annual fatality rate with 95% exhibiting collision avoidance (birds/turbine/year = V*Z*0.05)	0.01775	0.02354	0.00984	0.01305
Annual fatality rate with 99% exhibiting collision avoidance (birds/turbine/year = V*Z*0.01)	0.00355	0.00471	0.00197	0.00261

[1] Used 100% fatality probability due to ESA definition of "take", however actual probability of fatality with collision <100% (see methods).

estimate that ~348 Hawaiian Petrels and ~193 Newell's Shearwaters pass over the 1.5-km-radius radar sampling areas in an average year (including birds at all altitudes; Table 2). To generate annual exposure rates of birds exposed to each turbine (e.g., birds/turbine/yr), we then multiplied the annual movement rate by the horizontal-interaction probability and the vertical-interaction probability. By applying those proportions to our data (and rounding up to the nearest whole number), we estimate that 1–3 Hawaiian Petrels and 1–2 Newell's Shearwaters fly within the space occupied by each turbine in an average year (Tables 2 and 3). Note that all these calculations are exposure rates and, thus, include an unknown proportion of birds that would detect and avoid the turbines. Hence, exposure rates estimate how many times/year a petrel or shearwater would be exposed to turbines and not necessarily the number that actually would collide with these structures.

FATALITY MODELING

The individual steps and estimates involved in calculating fatality rates for proposed wind turbines are shown in Table 2. We speculate that the proportions of birds that detect and avoid turbines is substantial (see Discussion), but only limited petrel- or shearwater-specific data are available to use for an estimate of these factors for turbines. Because it is necessary to estimate the fatality of petrels and shearwaters at the proposed project, however, we assumed that 90%, 95%, or 99% of all birds will be able to detect and avoid the turbines. If we also assume that 100% of the birds colliding with a turbine die (although see above), the ranges of annual fatalities are 0.004–0.047 Hawaiian Petrel/turbine/yr and 0.002–0.026 Newell's Shearwaters/turbine/year for each turbine (Table 3). Looking at the cumulative annual fatalities, the annual fatality rate would be 0.050–0.659 Hawaiian Petrels/yr and 0.028–0.366 Newell's Shearwaters/yr for all 14 proposed wind turbines combined (Table 3). We caution again, however, that the range of assumed avoidance rates of seabirds and wind turbines (90–99%) is not fully supported by empirical data at this time.

DISCUSSION

EXPOSURE RATES AND FATALITY ESTIMATES

We estimated that 0.4–2.4 Hawaiian Petrels and 0.2–1.3 Newell's Shearwaters would fly within the space occupied by each turbine, per year (Table 3). We used these estimated exposure rates as a starting point for developing a complete avian risk assessment; however, we emphasize that it currently is unknown whether bird use (i.e., exposure) and fatality at windfarm structures are strongly correlated. For example, Cooper and Day (1998) found no relationship between movement rates and fatality rates of Hawaiian Petrels and Newell's Shearwaters at powerlines on Kaua'i, indicating that other factors had a much greater effect on causing fatality than movement rates did. For example, other factors such as proximity to the ocean or poor weather could be more highly correlated with fatality rates than is bird abundance. As an example, collisions of Laysan Albatross with a large array of communication-tower antenna wires and guy wires adjacent to large, high-density albatross breeding colonies on Midway Atoll occurred at a far higher rate during periods of high winds, rain, and poor visibility: 838 (>25%) of the 2,901 birds killed during the 1.5-yr-long study were killed during two storms (Fisher 1966). To determine which factors are most relevant, future studies that collect concurrent data on movement rates, weather, and fatality rates would be useful to begin to determine whether movement rates and/or weather conditions can be used to predict the likelihood of petrel fatalities at wind turbines and other structures across the entire proposed windfarm.

In addition to these questions about the unknown relationships among abundance, weather, and fatality, few data are available on the proportion of petrels and shearwaters that do not collide with wind turbines because of collision-avoidance behavior (i.e., birds that completely alter their flight paths horizontally and/or vertically to avoid flying through the space occupied by a wind turbine). Clearly, the detection of wind turbines or other structures could result in collision-avoidance behavior by these birds and reduce the likelihood of collision. In addition, there

Table 3. Summary of exposure rates, fatality rates, and cumulative fatality rates for Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at wind turbines at the proposed KWP II wind energy facility, Maui, Hawaii, based on radar data collected in summer (July) and fall (October) 2008.

Structure type	Exposure rate/turbine (birds/turbine/yr)		Avoidance Rate	Fatality rate/turbine (birds/turbine/yr)		No. Structures	Cumulative fatality rate (birds/yr)	
	HAPE	NESH		HAPE	NESH		HAPE	NESH
GE 1.5 MW turbine	0.355 (min)	0.197 (min)	0.90 (min)	0.036	0.020	14	0.497	0.276
	2.414 (max)	1.339 (max)	0.90 (max)	0.047	0.026	14	0.659	0.366
			0.95 (min)	0.018	0.010	14	0.249	0.138
			0.95 (max)	0.024	0.013	14	0.330	0.183
			0.99 (min)	0.004	0.002	14	0.050	0.028
			0.99 (max)	0.005	0.003	14	0.066	0.037

appear to be differences between petrels and shearwaters in their ability to avoid obstacles. For example, Cooper and Day (1998) indicated that Hawaiian Petrels have flight characteristics that make them more adept at avoiding powerlines than Newell's Shearwaters, suggesting that Hawaiian Petrels might also be more likely to avoid collisions with other structures (e.g., wind turbines). These authors also suggested that the tendency for Hawaiian Petrels to approach and leave nesting colonies primarily during crepuscular periods enables these birds to see and avoid structures (e.g., wind turbines) more easily than Newell's Shearwaters that approach and leave nesting colonies primarily during nocturnal periods.

There is some collision-avoidance information available on petrels and shearwaters from earlier work that we conducted on Kaua'i (Cooper and Day 1998; Day and Cooper unpubl. data). In summary, those data suggest that the behavioral-avoidance rate of Hawaiian Petrels and Newell's Shearwaters near powerlines is high. For example, although we were unable to calculate an avoidance rate *per se* for the Kaua'i data, none (0%) of the 207 Hawaiian Petrels and none (0%) of the 392 Newell's Shearwaters that passed within 150 m of a powerline collided with it. These 599 birds probably include a substantial proportion of petrels and shearwaters that had flight paths that did not require a course correction to avoid the powerline; however, even when we examined only birds that flew within 25 m of a powerline, they found that 0 of 71 (0%) of all petrels and 0 of 113 (0%) shearwaters collided with the lines. Further, all 50 petrels and 34 shearwaters that were observed reacting to the lines were able to avoid collision (i.e., a 100% avoidance rate for those subsets of birds, if one assumes that without avoidance, all those birds would have collided with the lines).

There also is some information available on collision-avoidance of Hawaiian Petrels on Lana'i, where the behavior of petrels was studied as they approached large communication towers near the breeding colony (TetraTech 2008). In that study, all 20 (100%) of the Hawaiian Petrels seen on a collision-course toward communication towers exhibited avoidance behavior and avoided collision.

Additional data that provides some insight on collision-avoidance behavior of petrels and shearwaters at windfarm structures (e.g., met towers and wind turbines) are available from other studies associated with the operational KWP I wind facility. There was 1 Hawaiian Petrel fatality and 0 Newell's Shearwater fatalities observed at the 20-turbines and three met towers in the first 33 months of operation (G. Spencer, First Wind, pers. comm.). Calculations using data for scavenging bias and searcher efficiency collected at the KWP I wind facility (First Wind 2008) indicate that the one observed fatality equates to a corrected direct take of ~1.2 Hawaiian Petrels/yr and 0.0 Newell's Shearwaters/yr (D. Cowan, First Wind, pers. comm.). Cooper and Day (2004b) modeled seabird fatality for the KWP I wind turbines, based on movement rates from radar studies at the site (Day and Cooper 1999; Cooper and Day 2004a, 2004b) and estimated that the combined annual fatality of Hawaiian Petrels and Newell's Shearwaters at the KWP I turbines would be ~3–18 birds/yr with a 50% avoidance rate, ~1–2 birds/yr with a 95% avoidance rate, and <1 bird/yr with a 99% avoidance rate. Thus, the fatality model using a 95% avoidance value was a closer fit with the measured fatality rates than the fatality model using a 50% avoidance rate.

In summary, the currently available data from Kaua'i, Lana'i, and Maui suggest that the avoidance rate of petrels and shearwaters at transmission lines and communications towers is high. Data from the fatality searches at turbines and met towers on Maui are more difficult to interpret (because they suggest high avoidance but are not a direct measure of avoidance), however those data also suggest that avoidance of those structures must be occurring since only one Hawaiian Petrel has been found during regular fatality searches of those structures over a three-year (33 month) period. Thus, the overall body of evidence, while incomplete, is consistent with the notion that the average avoidance rate of wind turbines and other structures at windfarms is substantial and potentially is as high as 95%. The ability of Hawaiian Petrels and Newell's Shearwater to detect and avoid most objects under low-light conditions makes sense from a life-history standpoint, in that they forage extensively at night and are adept at flying through forests near their nests during those light conditions.

In addition to the limited data available for Hawaiian Petrels and Newell's Shearwaters, there is evidence that many other species of birds detect and avoid structures (e.g., met towers and wind turbines) during low-light conditions (Winkelman 1995, Dirksen et al. 1998, Desholm and Kahlert 2005, Desholm et al. 2006). For example, seaducks in Europe have been found to detect and avoid wind turbines >95% of the time (Desholm 2006). Further, natural anti-collision behavior (especially alteration of flight directions) is seen in migrating Common and King eiders (*Somateria mollissima* and *S. fischeri*) approaching human-made structures in the Beaufort Sea off of Alaska (Day et al. 2005) and in diving ducks approaching offshore windfarms in Europe (Dirksen et al. 1998). Collision-avoidance rates around wind turbines are high for Common Eiders in the daytime (Desholm and Kahlert 2005), gulls (*Larus* spp.) in the daytime (>99%; Painter et al. 1999, cited in Chamberlain et al. 2006), Golden Eagles (*Aquila chrysaetos*) in the daytime (>99%; Madders 2004, cited in Chamberlain et al. 2006), American Kestrels (*Falco sparverius*) in the daytime (87%, Whitfield and Band [in prep.], cited in Chamberlain et al. 2005), and passerines during both the day and night (>99%; Winkelman 1992, cited in Chamberlain et al. 2006).

We agree with others (Chamberlain et al. 2006, Fox et al. 2006) that species-specific, weather-specific, and site-specific avoidance data are needed in models to estimate fatality rates accurately. However, the currently available avoidance data from Kaua'i and Lana'i for Hawaiian Petrels and Newell's Shearwaters and the petrel fatality data at KWP I wind turbines and met towers (one killed to date), while incomplete, is consistent with the notion that a substantial proportion of petrels detect and avoid wind turbines, marked met towers, communication towers, and powerlines under normal ranges of weather conditions and visibility (but note that avoidance rates could be lower under inclement conditions). Until further petrel- and shearwater-specific data on the relationship between exposure and fatality rates are available for structures at windfarms, we continue to provide a range of assumptions for avoidance rates in our fatality models (i.e., 90%, 95%, and 99% avoidance) along with a discussion of the body of evidence that, while incomplete at this time, is consistent with the notion that the average avoidance-rate value is substantial and potentially is as high as 95%. With a 95% assumption, the estimated average annual take at KWP II would be <0.1 Hawaiian Petrel/turbine/year and <0.1 Newell's Shearwaters/turbine/year.

There are additional factors that could affect our estimates of fatality, both in a positive and a negative direction. One factor that would have created a positive bias was the inclusion of targets that were not petrels or shearwaters. Our visual observations (especially during crepuscular periods, when we could use binoculars) probably helped to minimize the inclusion of non-target species, but it is possible that some of our radar targets were other fast-flying species that were active during the sampling period (e.g., Hawaiian Nene [*Branta sandvicensis*]). A second positive bias in our fatality model is our simplistic assumption that movement rates of seabirds did not fall as individual fatalities occurred (i.e., we assumed sampling with replacement for fatalities). Given the low movement rates observed in this study, it is likely that the fatality of just a single bird would substantially reduce the average nightly movement rates. A third positive bias is the assumption that turbines are operating at maximum rotor speed. Clearly because of variability in winds there are periods when actual rotor speeds are less than the maximum (or turbines will be inactive) and this affects estimates of the probability of collision if a bird enters the airspace occupied by a turbine.

There also are factors that could create a negative bias in our fatality estimates. One example would be if targets were missed because they flew within radar shadows. Because the sampling stations provided good coverage of the surrounding area, we believe that the proportion of targets that was missed because they passed through the entire area of coverage of the study area within a radar shadow was minimal.

A factor that could affect the predictive value of our fatality estimates in either direction is interannual variation in seabird counts. The average hourly movement rate for the current study (summer = ~0.5 targets/hr, fall = ~0.1 targets/hr) and from summer 1999 (1.2 targets/hr; Day and Cooper 1999) and fall 2004 (1.0 targets/hr; Cooper and Day 2004a) suggests that rates are consistently very low at the KWP project areas and that interannual variation is minimal. Some caution in extrapolation of movement rates across years is still warranted, however, as there are examples of other sites with high interannual variation in counts, such as the three sites on Kaua'i where counts were ~100–300 birds/hr lower (~four times lower) in fall 1992 than in fall 1993; the lower counts in 1992 were attributed to the effects of Hurricane Iniki (Day and Cooper 1995). Oceanographic factors (e.g., El Niño–Southern Oscillation events) also vary among years and are known to affect the distribution, abundance, and reproduction of seabirds (e.g., Ainley et al. 1994, Oedekoven et al. 2001). Another factor that could cause interannual variation in counts in either direction is overall population increases or declines. For example, there was a ~60% decline in radar counts between 1993 and 1999–2001 that was attributed to population declines of Newell's Shearwaters (Day et al. 2003b).

CONCLUSIONS

We used our risk-assessment model to estimate the number of Hawaiian Petrels and Newell's Shearwaters that might be killed by collisions with wind turbines at the proposed KWP II facility. The model is affected by several input variables; however, the collision-avoidance rate variable has a large effect on modeled estimates and is one of the most-poorly-understood variables at this time. The absence of adequate studies at other sites preclude determination of actual avoidance rates; however, there is a body of evidence for petrels at communication towers, transmission lines, and wind turbines that suggests that a high percentage of petrels detect and avoid structures (see above). In particular, fatality data from the Maui KWP I windfarm suggests that avoidance rates are high. We also suspect high rates of anti-collision behaviors because petrels must rely upon acute nocturnal vision for foraging and other flight activities under varying weather conditions and because many petrels travel to and from nest colonies while there is still light in the sky. In conclusion, we believe that the proportion of petrels that would see and avoid proposed wind turbines at KWP II will be high, but emphasize that, until studies are conducted and data are available on avoidance behavior at wind turbines, the exact proportion will remain unknown. As a result, we have provided a range of assumptions for avoidance rates in our fatality models (i.e., 90%, 95%, and 99% avoidance rates) along with a discussion of the body of evidence that, while incomplete at this time, is consistent with the notion that the average avoidance-rate value is substantial and potentially is as high as 95%. With an assumption of 95% avoidance, the estimated average annual take at the proposed KWP II wind turbines would be <0.1 Hawaiian Petrel/turbine/year and <0.1 Newell's Shearwaters/turbine/year.

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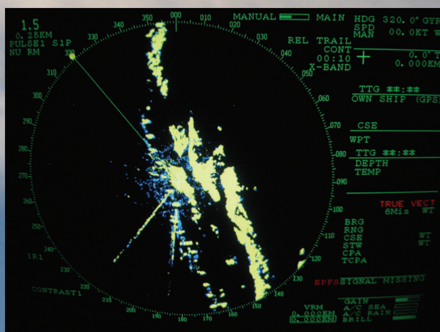
Appendix 4

RADAR AND VISUAL STUDIES OF SEABIRDS AT THE KWP I AND II WIND ENERGY FACILITIES, MAUI ISLAND, HAWAII: USE OF 2008 DATA TO MODEL ANNUAL COLLISION FATALITIES AT METEOROLOGICAL TOWERS

PETER M. SANZENBACHER

BRIAN A. COOPER



PREPARED FOR

FIRST WIND
NEWTON, MASSACHUSETTS

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FOREST GROVE, OREGON

RADAR AND VISUAL STUDIES OF SEABIRDS AT THE KWP I AND II WIND ENERGY FACILITIES, MAUI ISLAND, HAWAII: USE OF 2008 DATA TO MODEL ANNUAL COLLISION FATALITIES AT METEOROLOGICAL TOWERS

FINAL REPORT

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EXECUTIVE SUMMARY

- We used radar and visual methods to collect data on movements of endangered Hawaiian Petrels (*Pterodroma sandwichensis*) and threatened Newell's (Townsend's) Shearwaters (*Puffinus auricularis newelli*) at the operational Kaheawa Pastures Wind Energy Generation Facility (KWP I) and proposed expansion, Kaheawa Wind Power II (KPW II), on Maui Island during summer and fall 2008. We conducted evening and morning surveys during 10 nights of sampling each season from 13–22 July in summer and 21–30 October in fall.
- The objectives of the study were to 1) document movement rates of Hawaiian Petrels and Newell's Shearwaters at two sampling stations with coverage of KWP I and KWP II areas, (2) estimate the daily number of petrels/shearwaters that fly within areas that are occupied by met towers at the KWP I facility and met towers at the proposed KWP II project, and (3) estimate annual fatality rates of petrels/shearwaters at KWP I and KWP II met towers.
- We recorded 19 radar targets that fit our criteria for petrels and shearwaters during 40.6 hours of sampling in summer. Of these targets, we recorded 7 at the upper sampling station and 12 at the lower sampling station. In the fall we recorded 4 targets that fit our criteria for petrels and shearwaters during 38.9 hrs sampling. All of these targets were recorded at the lower station.
- The mean movement rate across both stations and all nights was 0.456 ± 0.15 targets/hr during summer and 0.094 ± 0.07 targets/hr during fall. Mean movement rates during summer were 0.336 ± 0.12 targets/hr at the upper station and 0.576 ± 0.16 targets/hr at the lower station. Mean movement rates during fall were 0.0 targets/hr at the upper station and 0.188 ± 0.09 targets/hr at the lower station. After adjusting our sampling results for hours of the night that we did not sample (i.e., non-peak periods), we estimated a mean movement rate across all sampling stations of 2.8 petrel-like targets/night during summer and 0.6 petrel-like targets/night during fall
- We did not detect any petrel/shearwater targets during visual sampling, using binoculars and night-vision methodologies.
- To determine the risk of collision-caused mortality, we used petrel/shearwater movement rates observed on radar in summer and fall 2008, petrel/shearwater flight altitudes from previous studies, and dimensions and characteristics of the KWP I and KWP II met towers to generate an estimate of exposure risk. To this estimate of exposure, we then applied estimates of the fatality probability (i.e., the probability of death if a bird collides with a structure) and a range of estimated avoidance probabilities in order to calculate annual fatality rates that could be expected at the met towers.
- We estimate that ~348 Hawaiian Petrels and ~193 Newell's Shearwaters pass over the radar sampling area annually.
- We estimated annual fatality rates at met towers by assuming that 90%, 95%, or 99% of all petrels/shearwaters flying near a met tower will see and avoid the tower. Based on these scenarios, annual fatality rates ranged from 0.004–0.039 Hawaiian Petrels/tower/yr and 0.002–0.022 Newell's Shearwaters/tower/year for the one 30-m met tower; 0.012–0.115 Hawaiian Petrels/tower/yr and 0.006–0.064 Newell's Shearwaters/tower/yr for the four 50-m met towers; and 0.014–0.138 Hawaiian Petrels/tower/yr and 0.008–0.077 Newell's Shearwaters/tower/yr for the two 55-m met towers. Although the range of assumed avoidance rates of seabirds and met towers (90–99%) is not fully supported by empirical data at this time we speculate that avoidance rates of petrels and shearwaters at wind farm structures (e.g., met towers) are most likely high (>90%), based upon fatality rates at existing windfarms and avoidance behavior of petrels observed at other structures (e.g., powerlines and communication towers), and thus expect that fatality rates will be toward the low end of the range of estimates.

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ACKNOWLEDGMENTS

We thank First Wind for funding this study and also providing the ornithological radar used for sampling. We thank Greg Spencer and Dave Cowan (First Wind) for help with logistics and thank Greg Spencer, Ian Bordenave, and Bob Roy (First Wind) for their assistance with the radar and visual sampling. Makena White at Planning Solutions, Inc. (Honolulu, Hawaii) provided GIS data for study figures. At ABR, Dorte Dissing produced study figures and Pam Odom assisted with report production.

INTRODUCTION

First Wind, formerly UPC Wind Management, LLC, operates the 30 MW Kaheawa Pastures Wind Energy Generation Facility, referred to as Kaheawa Wind Power (KWP I), on the island of Maui (Figure 1). A new wind project adjacent to the existing facility will be developed by First Wind and operated as Kaheawa Wind Power II (KWP II). Two federally-listed seabird species occur on Maui: the endangered Hawaiian Petrel (*Pterodroma sandwichensis*; Hawaiian name: 'Ua'u) and the threatened Newell's (Townsend's) Shearwater (*Puffinus auricularis newelli*; Hawaiian name: 'A'o). Ornithological radar and night-vision techniques have been shown to be successful in assessing numbers and movement rates of petrels and shearwaters on the Hawaiian Islands (e.g., Kaua'i [Cooper and Day 1995, 1998; Day and Cooper 1995, Day et al. 2003b], Maui [Cooper and Day 2003], Moloka'i [Day and Cooper 2002] and Hawai'i [Reynolds et al. 1997, Day et al. 2003a]). Previous radar and visual studies documented the presence of petrel/shearwater targets in the vicinity of the KWP I project site, including visual observations of Hawaiian Petrels (Day and Cooper 1999, Cooper and Day 2004a). These data were used to model the potential number of annual fatalities at the KWP I development (Cooper and Day 2004b).

The currently operational KWP I wind energy facility consists of one 30-m-high, guyed NRG monopole meteorological (met) tower, two 55-m-high, guyed lattice-style met towers, and an articulated row of 20 1.5-MW turbines (Figure 2). The KWP II project currently consists of four operational 50-m-high, guyed NRG monopole met towers and ~14 proposed 1.5-MW turbines (GE 1.5se), each with a hub height of ~65 m and a rotor diameter of 70.5 m.

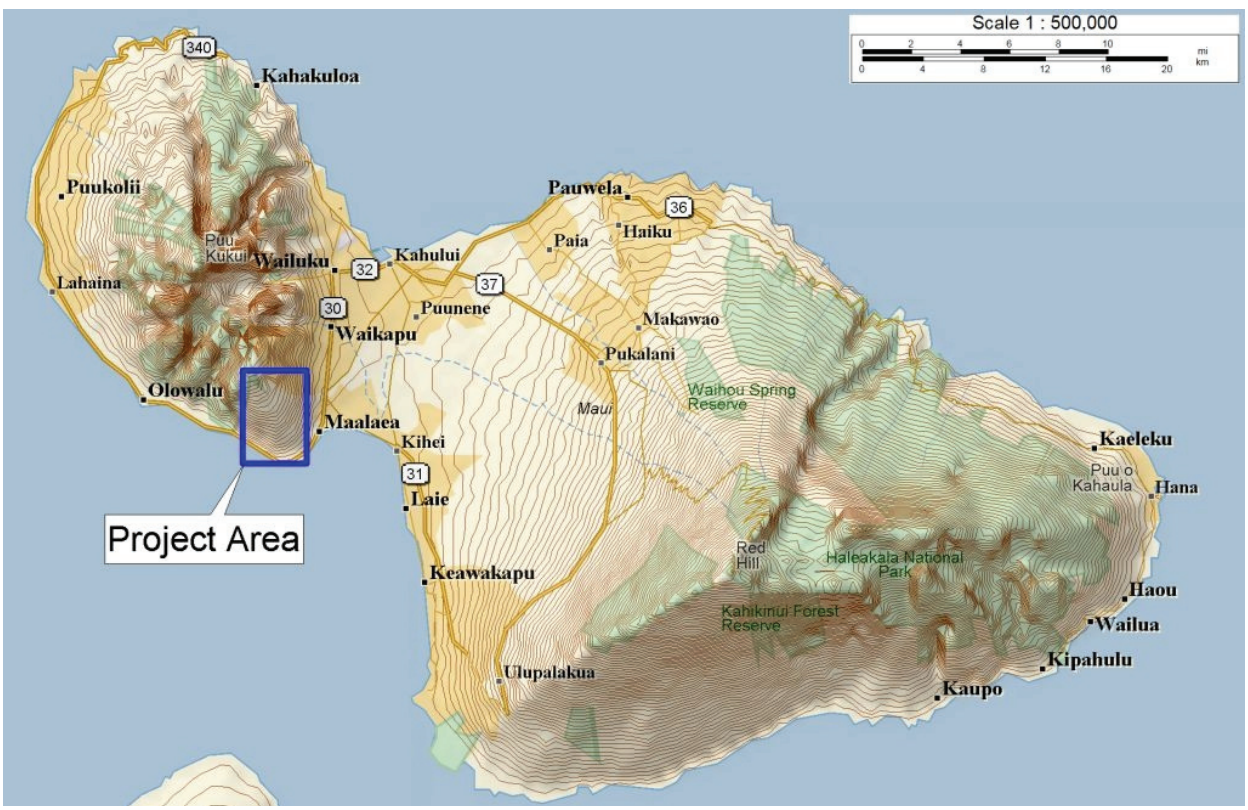

Figure 1. Maui Island, Hawaii, with approximate location of the Kaheawa Pastures Wind Energy Facilities (KWP I and KWP II).

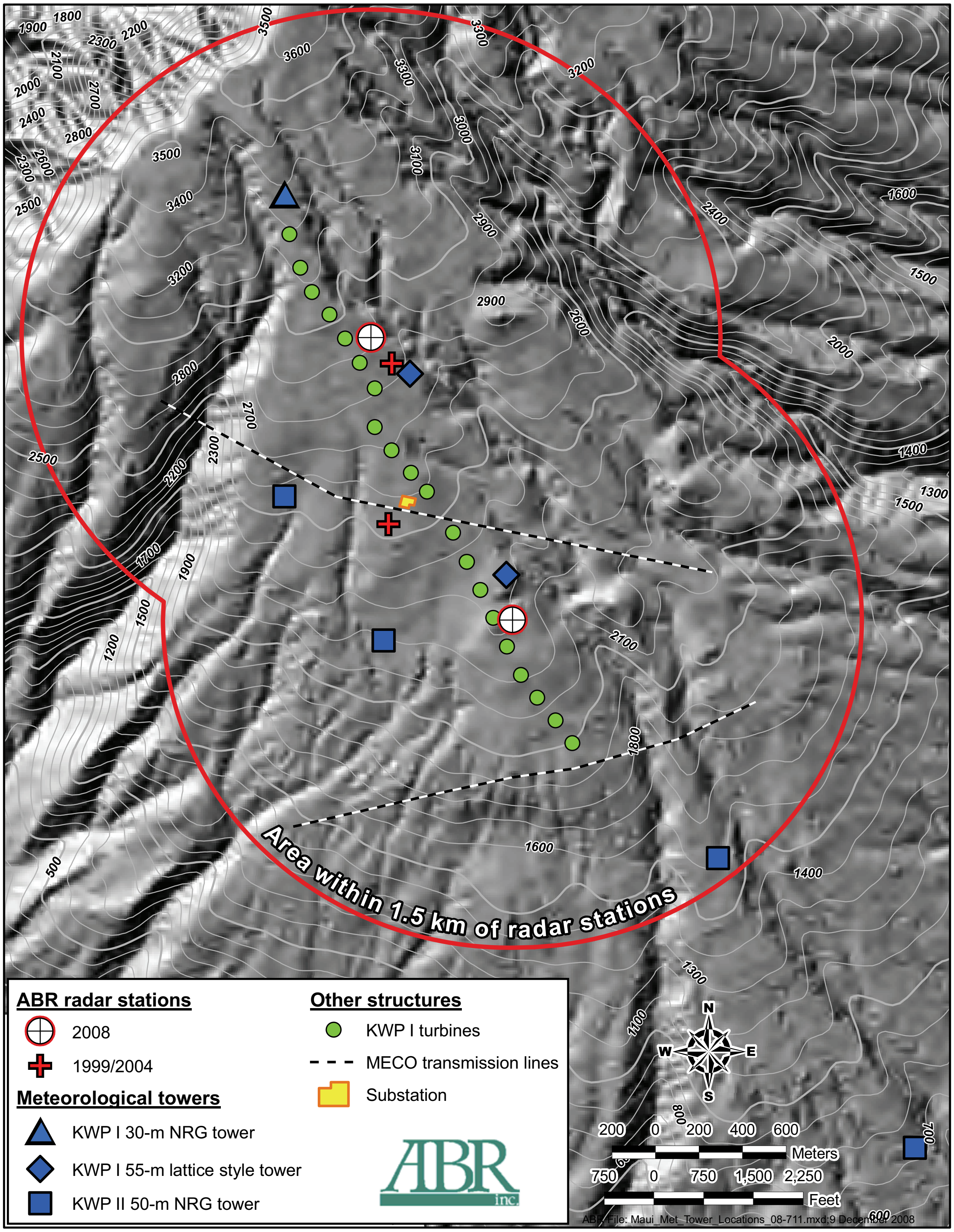

Figure 2. Location of 2008 radar sampling stations relative to previous radar sampling stations (Day and Cooper 1999, Cooper and Day 2004a) and existing structures at the KWP I and KWP II wind energy facilities, Maui, Hawaii.

ABR conducted additional radar and visual studies on Maui in July and October 2008 with a specific focus on areas proposed for the KWP II development. In this report we present a summary of results from these studies including (1) movement rates of Hawaiian Petrels and Newell's Shearwaters at two sampling stations with coverage of KWP I and also areas proposed for the KWP II development, (2) estimates of the daily number of petrels that fly within the areas occupied by met towers at the KWP I facility and proposed KWP II project, and (3) estimates of annual fatality rates of petrels at KWP I and KWP II met towers.

BACKGROUND

Two seabird species that are protected under the Endangered Species Act (ESA) are likely and/or known to occur in the KWP I and KWP II project areas: the endangered Hawaiian Petrel and the threatened Newell's (Townsend's) Shearwater. The Hawaiian Petrel ('Ua'u) and the Newell's Shearwater ('A'o) are forms of tropical Pacific species that nest only on the Hawaiian Islands (American Ornithologists' Union 1998). Both species are Hawaiian endemics whose populations have declined significantly in historical times: they formerly nested widely over all of the Main Islands but now are restricted in most cases to scattered colonies in more inaccessible locations (Ainley et al. 1997b, Simons and Hodges 1998). The one exception is Kaua'i Island; there, colonies still are widespread and populations are substantial in size. Of note, Kaua'i (along with Lana'i) also has no introduced Indian Mongooses (*Herpestes auropunctatus*) which prey on these seabirds. Because of their low overall population numbers and restricted breeding distributions, both of these species are protected under the Endangered Species Act.

The Hawaiian Petrel is known to nest primarily on Maui (Richardson and Woodside 1954, Banko 1980a; Simons 1984, 1985; Simons and Hodges 1998, Cooper and Day 2003), Kaua'i (Telfer et al. 1987, Gon 1988, Day and Cooper 1995; Ainley et al. 1995, 1997a, 1997b; Day et al. 2003a), Hawai'i (Banko 1980a, Conant 1980, Hu et al. 2001, Day et al. 2003a), Lana'i (Shallenberger 1974; Hirai 1978a, 1978b; Conant 1980; G. Spencer and J. Penniman, pers. comm.), and Moloka'i (Simons and Hodges 1998, Day and Cooper 2002). On Maui, these petrels are known to nest on Haleakala Crater (Brandt et al. 1995, Simons and Hodges 1998) and recent observations of birds calling and exhibiting aerial displays consistent with breeding behavior indicate the presence of Hawaiian Petrel nesting colonies in West Maui despite the minimal historical evidence and introduction of Indian Mongoose on Maui. For example, on 16 June 1999, a Hawaiian Petrel was heard calling from a bed of uluhe ferns (*Dicranopteris linearis*) at 3,300 ft elevation in the Kapunakea Preserve, which lies on the northwestern slope of the West Maui Natural Area Reserve (A. Lyons, *fide* C. Bailey). Further, Cooper and Day (2003) observed Hawaiian Petrels flying inland over the northern coast toward West Maui Mountain. In addition, recent observations of consistent calling from a single location suggests that there is another small colony of Hawaiian Petrels in the west Maui Mountains ~14 km north of the KWP project areas (G. Spencer, First Wind, pers. comm.). Daily movement rates of Hawaiian Petrels near KWP I and II (i.e., on the southern slope of West Maui Mountain) are much lower than those over the eastern and northern sides of Maui (Cooper and Day 2003).

Newell's Shearwaters nest on several of the main Hawaiian Islands, with the largest numbers clearly occurring on Kaua'i (Telfer et al. 1987, Day and Cooper 1995, Ainley et al. 1995, 1997b, Day et al. 2003b). These birds also nest on Hawai'i (Reynolds and Richotte 1997, Reynolds et al. 1997, Day et al. 2003a), almost certainly nest on Moloka'i (Pratt 1988, Day and Cooper 2002), and may still nest on O'ahu (Sincock and Swedberg 1969, Banko 1980b, Conant 1980, Pyle 1983; but see Ainley et al. 1997b). On Maui, recent auditory observations suggest that a small colony of Newell's Shearwaters is present in the west Maui Mountains ~14 km north of the KWP project areas (G. Spencer, First Wind, pers. comm.). Newell's Shearwaters typically nest on steep slopes that are vegetated by uluhe fern (*Dicranopteris linearis*) undergrowth and scattered ohia trees (*Metrosideros polymorpha*).

There is interest in studying these two species because of concerns regarding collisions with structures such as met towers and wind turbines. To date, there is documented mortality of only one Hawaiian Petrel (at a wind turbine; G. Spencer, First Wind, pers. comm.) and zero Newell's Shearwaters at wind energy facilities within the Hawaiian Islands. Note, however, that fatality studies have been conducted for only three years (33 months) at one wind energy location in the Hawaiian Islands (Maui), plus a three-month-long fatality study of six met towers at the same site prior to operation. Therefore, there have not been enough studies of adequate duration to definitively answer the question on whether these species are prone to collisions at these structures. Of note, there has been petrel and shearwater mortality because of collisions with other human-made objects (e.g., transmission lines) on Kaua'i (Telfer et al. 1987, Cooper and Day 1998, Podolsky et al. 1998) and Maui (Hodges 1992). In addition, there have been collision-caused fatalities of other seabirds at other Pacific Islands. For example, nearly 2 million seabirds comprising 18 different species nest on Midway Atoll (USFWS 2008) and collisions with antenna wires and guyed lattice towers sited near these seabird nesting colonies with high densities of birds has resulted in fatalities of Laysan Albatrosses (*Diomedea immutabilis*), Black-footed Albatrosses (*Diomedea nigripes*), Wedge-tailed Shearwaters (*Puffinus pacificus*), Bonin Petrels (*Pterodroma leucoptera*), Red-tailed Tropicbirds (*Phaethon rubricauda*), Sooty Terns (*Sterna fuscata*), and a Bulwer's Petrel (*Bulweria bulwerii*, Fisher 1966).

STUDY AREA

The operational KWP I wind energy facility and proposed KWP II expansion are located on the southern slope of West Maui Mountain, in an area called Kaheawa Pastures (Figure 1). These sites lie on a gently sloping portion of West Maui Mountain, ~6 km inland from McGregor Point. Vegetation at the site consists of grasslands at lower elevations and a mixture of grasslands and scattered shrubs at moderate to higher elevations. Shrubs and scattered trees line the nearby gulches and directly above the site, shrubs dominate, with native ohia trees (*Metrosideros polymorpha*) and uluhe ferns becoming more common. Although the site consists of a dry Mediterranean habitat, vegetation becomes much wetter upland, toward the summit of West Maui Mountain. Presumably, vegetation communities also are dominated by native species in these higher, wetter areas. These more upland habitats appear as suitable nesting habitat for Newell's Shearwaters, based on our experience on Kaua'i and other sites. In addition to the vegetation, the steepness of higher elevations on West Maui Mountain also suggests suitable nesting habitat exists for Hawaiian Petrels, as it does on Haleakala (Brandt et al. 1995), Kaua'i (Telfer, pers. comm.), and Lana'i (Hirai 1978b).

In previous studies at the site (Day and Cooper 1999, Cooper and Day 2004a) sampling was conducted at the same two stations, however, for the current studies we established two new sampling stations with a focus on providing maximum radar coverage of potential locations of the proposed KWP II development situated slightly to the east, west, and south of the existing KWP I turbine string (Figure 2). Similar to previous studies one station was on the northern (upper) end of the study area (20° 49'14 N, 156° 33'10 W; ~899 m above sea level; Datum = WGS84); and one was on the southern (lower) end of the study area (20° 48'32" N, 56° 32'49" W; ~725 m above sea level).

METHODS

We used marine radar and visual equipment to collect data on the movements, flight behaviors, and flight altitudes of petrels and shearwaters at two sampling stations during summer (13–22 July) and fall (21–30 October) 2008 (Table 1). We attempted to sample an equal number of days at both the upper station and lower station during each season and the daily sampling effort consisted of 3 h/evening (summer = 1900–2200 hrs, fall = 1800–2100) and 2 h/morning (summer = 0400–0600 hrs, fall = 0430–0630). These sampling periods were selected to correspond to the evening and morning peaks of movement of petrels and shearwaters, as described near breeding colonies on Kaua'i (Day and Cooper 1995). During sampling, we collected radar and visual data concurrently so the radar operator could help the visual observer locate birds for species identification and data collection. In return, the visual observer provided information to the radar operator on the identity and flight altitude of individual targets (whenever possible). For the

Table 1. Sampling dates, number of landward and seaward seabird radar targets, and number of audio-visual and acoustic observations of species of interest, Maui Island, Hawaii, July and October 2008.

			Number of radar targets			Number of audio-visual detections[1]	
Date	Station	Period	Landward[2]	Seaward[2]	Total	Visual	Acoustic
13 July	Upper	Eve	0	1	1	0	0
		Morn	0	1	1	0	0
14 July	Upper	Eve	0	0	0	1 SEOW	0
		Morn	0	0	0	0	0
15 July	Upper	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
16 July	Upper	Eve	1	2	3	0	0
		Morn	0	0	0	0	0
17 July	Upper	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
18 July	Lower	Eve	0	2	2	0	0
		Morn	0	0	0	0	0
19 July	Lower	Eve	0	5	5	0	0
		Morn	0	0	0	0	0
20 July	Lower	Eve	1	1	2	0	0
		Morn	0	0	0	0	0
21 July	Lower	Eve	0	2	2	0	0
		Morn	0	0	0	0	0
22 July	Lower	Eve	0	1	1	0	0
		Morn	0	0	0	0	0
21 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	2 SEOW	0
22 Oct	Upper	Eve[3]	-	-	-	-	-
		Morn	0	0	0	0	0
23 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
24 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
25 Oct	Lower	Eve	0	0	0	0	0
		Morn	0	1	1	0	0
26 Oct	Lower	Eve	1	0	1	1 SEOW	0
		Morn	0	1	1	2 NENE	0
27 Oct	Lower	Eve	0	0	0	1 HOBA, 1 PGPL	0
		Morn	0	0	0	0	0
28 Oct	Lower	Eve	0	0	0	1 HOBA	0
		Morn	0	1	1	0	0
29 Oct	Lower	Eve	0	0	0	0	0
		Morn	0	0	0	0	0
30 Oct	Upper	Eve	0	0	0	0	0
		Morn	0	0	0	0	0

[1] Species codes refer to HOBA = Hoary Bat (*Lasiuris cinereus semotus*), NENE = Hawaiian Nene (*Branta sandvicensis*), PGPL = Pacific Golden Plover (*Pluvialis fulva*), SEOW = Short-eared Owl (*Asio flammeus sandwichensis*).
[2] Flight direction categories for landward and seaward categories included all birds flying toward and away, respectively, from either the colonies located on the opposite end of west Maui to the north of the study site or colonies on Haleakala.
[3] No sampling conducted due to logistical issues.

purpose of recording data, a calendar day began at 0700 and ended at 0659 the following morning; that way, an evening and the following morning were classified as occurring on the same day.

The ornithological radar used in this study was a Furuno (Model FCR-1510) X-band radar transmitting at 9.410 GHz through a slotted wave guide with a peak power output of 12 kW; a similar radar unit is described in Cooper et al. (1991) and Mabee et al. (2006). The antenna face was tilted upward by ~10–15°, and we operated the radar at a range setting of 1.5 km and a pulse-length of 0.07 μsec.

Issues associated with radar sampling include ground clutter and shadow zones. Whenever energy is reflected from the ground, surrounding vegetation, and other objects around the radar unit, a ground-clutter echo appears on the radar's display screen that can obscure targets of interest (i.e., birds). Shadow zones are areas of the screen where birds can fly at an altitude that would potentially put them behind a hill or row of vegetation where they could not be detected because the radar operates only on line-of-sight. We attempted to minimize ground clutter and shadow zones during the selection of radar sampling stations and various structures and landscape features visible on radar indicated that our sampling stations provided good coverage of the areas of interest.

We sampled for six 25-min sessions during each evening period and for four 25-min sessions each morning (Table 1). We conducted an additional sampling session prior to official start time on some mornings in summer and fall, but the lack of targets suggested that our main sampling times were sufficient to encompass the morning period of peak petrel/shearwater activity. Each 25-min sampling session was separated by a 5-min break for collecting weather data. To help eliminate non-target species we collected data only for those targets that met a suite of selection criteria, following methods developed by Day and Cooper (1995), that included appropriate flight characteristics and flight speeds (≥30 mi/h [≥50 km/h]). We also removed radar targets identified by visual observers as other bird species.

We conducted visual sampling for birds and bats concurrently with the radar sampling to help identify targets observed on radar and to obtain flight-altitude information. During this sampling, we used 10X binoculars during crepuscular periods and Generation 3 night-vision goggles (Model ATN-PVS7; American Technologies Network Corporation, San Francisco, CA) during nocturnal periods. The magnification of the night-vision goggles was 1X, and their performance was enhanced with the use of a 3-million-Cp floodlight that was fitted with an IR filter to avoid blinding and/or attracting birds. Visual observations were conducted within 25 m of the radar to facilitate coordination between observers and we also listened for any petrel/shearwater vocalizations.

Before each 25-min sampling session, we also collected environmental and weather data, including:

- wind speed (to the nearest 1.6 km/h [1 mi/h]);
- wind direction (to the nearest 1°);
- percent cloud cover (to the nearest 5%);
- cloud ceiling height, in meters above ground level (agl; in several height categories);
- visibility (maximal distance we could see, in categories);
- light condition (daylight, crepuscular, or nocturnal, and with or without precipitation)
- precipitation type; and
- moon phase/position (lunar phase and whether the moon was above or below the horizon in the night sky).

For each appropriate radar target, we recorded the following data:

- species (if identified by visual observer);
- number of birds (if identified by visual observer);
- time;
- direction of flight (to the nearest 1°);
- cardinal transect crossed (000°, 090°, 180°, or 270°);

- tangential range (the minimal distance to the target when it passed closest to the radar; used in reconstructing actual flight paths, if necessary);
- flight behavior (straight, erratic, circling);
- velocity (to the nearest 5 mi/h [8 km/h]); and
- flight altitude (meters agl, if identified by visual observer).

For each bird (or bat) seen during night-vision sampling, we recorded:

- time;
- species (to the lowest practical taxonomic unit [e.g., Hawaiian Petrel, unidentified petrel/shearwater]);
- number of individuals composing each target;
- ordinal flight direction (000°, 045°, 090°, 135°, 180°, 225°, 270°, 315°); and
- flight altitude (meters agl).

For any birds heard but not observed, we recorded species, number of calls, direction of calls, and approximate distance.

DATA ANALYSIS

We entered all radar and visual data into Microsoft Excel databases. Data files were checked visually for errors after each night's sampling, then were checked electronically for irregularities at the end of the field season, prior to data analyses. All data summaries and analyses were conducted with SPSS 14.0 statistical software (SPSS 2005). Prior to analyses, radar data were filtered to remove non-target species and only known petrel/shearwater targets or unknown targets with appropriate characteristics (i.e., target size, flight characteristics, and airspeeds ≥30 mi/h) were included in data analyses. Airspeeds were calculated by correcting observed target flight speeds (groundspeeds) for speed and relative direction of wind, as measured each half hour at the radar station (Mabee et al. 2006).

We tabulated counts of numbers of radar targets recorded during each sampling session, then converted those counts to estimates of movement rates of birds (radar targets/h), based on the number of minutes sampled. Some sampling time was lost to rain or other factors; so we standardized estimates by actual sampling effort. We used all of the estimated movement rates across sampling sessions at a station to calculate the mean ± 1 standard error (SE) nightly movement rate by station and also lumped data across stations and nights to derive an overall hourly movement rate for the study.

We also classified general flight directions of each radar target as landward or seaward, and summarized those directional categories by station, date, and time period. To categorize the general flight direction of each target, we defined a landward flight as a radar target flying toward the west Maui Mountains or Haleakala on east Maui. Targets flying in the opposite directions were considered seaward targets.

MODELING FATALITY RATES

The risk-assessment technique that we have developed involves the use of radar data for estimating the fatality rates for petrels and shearwaters near structures in the Hawaiian Islands. This modeling technique uses the radar data on seasonal movement rates to estimate numbers of birds flying over the area of interest (sampling stations) across a 210-d year (for Newell's Shearwater) or 255-d year (for Hawaiian Petrels) when breeding birds are present on the island. The model then uses information on the physical characteristics of the structures (e.g., met towers) themselves to estimate horizontal and vertical interaction probabilities and combines these interaction probabilities with the movement rates to generate exposure rates. These exposure rates represent the estimated numbers of petrels/shearwaters that pass within the airspace occupied by a met tower and its associated guy wires at each site each year. We then combine these exposure rates with (1) the probability that an interaction results in fatality, and (2) the probability that birds detect met towers and avoid interactions, to estimate fatality rates.

We calculate an exposure rate by multiplying the seabird movement rate observed on radar by horizontal- and vertical-interaction probabilities. The movement rate is an estimate of the average number of birds passing in the vicinity of the proposed met towers in a day, as indicated by numbers of targets on the radar screen and the mean flock size/target. It is generated from the radar data by: (1) multiplying the average movement rates by 5.5 h to estimate the number of targets moving over the radar site in the first 3 h and last 2.5 h of the night (i.e., during the peak movement periods of petrel/shearwaters); (2) adjusting the sum of those evening and morning counts to account for the estimated percentage of movement that occurs during the middle of the night; and (3) multiplying that total number of targets/night by the mean number of seabirds/target to generate an estimate of the number of petrel/shearwaters passing in the vicinity of the met towers during an average day.

We used the radar-based movement data from our current study at the KWP project areas, with a focus on the proposed KWP II development, to estimate seabird movement-rates in both summer and fall and assumed that those rates represented average rates observed in an average year. We used data from all-night sampling sessions on Kaua'i (Day and Cooper 1995) to estimate movement rates occurring during the hours between our evening and morning sampling periods. These data suggested that an additional 12.6% of the total combined evening landward movements and seaward morning movements occurred between the evening and morning peak movement periods (Day and Cooper, unpubl. data). We also corrected the number of targets for flock size: mean flock sizes of petrels and shearwaters combined in Hawai'i are 1.05 ± SE 0.01 birds/flock (*n* = 2,062 flocks; Day and Cooper, unpubl. data). In addition, we used the timing of inland flights at the nearby Ukumehame site from Cooper and Day (2003) to correct for proportions of targets that were Hawaiian Petrels and those that were Newell's Shearwaters; those data suggested that 60% of the targets were Hawaiian Petrels and 40% of the targets were Newell's Shearwaters (see below).

The number of petrels visiting breeding colonies tends to decline from summer to fall because attendance at colonies by nonbreeders and failed breeders declines as chick-rearing progresses (Serventy et al. 1971, Warham 1990, Ainley et al. 1997b, Simons and Hodges 1998). Thus, we split the 255-d breeding season for Hawaiian Petrels (Simons and Hodges 1998) and 210-d breeding season for Newell's Shearwaters (Ainley et al. 1997b) into a spring/summer period (i.e., 180 days and 150 days for petrels and shearwaters, respectively) and a fall period (i.e., 75 days and 60 days for petrels and shearwaters, respectively). We corrected the seasonal estimates of nightly movement rates by the numbers of days for the spring/summer and fall seasons to generate estimates of movements for each season and species. We assume that the sum of these two estimates represents estimated movement rates for an entire breeding season (i.e., an average year).

Because the resulting estimate of the number of birds/yr is not an integer, we then round it upward to the next whole number to generate an estimate of the average number of birds passing within 1.5 km of the radar stations during a year. This rounding technique results in slightly-inflated fatality estimates, but we choose to take a conservative approach in these studies associated with endangered species.

INTERACTION PROBABILITIES

HORIZONTAL

Interaction probabilities consist of horizontal and vertical components. The horizontal-interaction probability is the probability that a bird seen on radar will pass through or over the airspace occupied by a met tower located somewhere on the radar screen. This probability is calculated from information on the two-dimensional area (side view) of the met tower and the two-dimensional area sampled by the radar screen to determine the interaction probability. The met-tower system has a central monopole or lattice tower with four sets of guy wires attached at five heights; hence, the tower/guy-wire system appears from the side to be an isosceles triangle (i.e., ~30 m high with a base of ~37 m for the 30-m met tower, ~50 m high with a base of 67 m for the 50-m met towers, and ~55 m high with a base of 80 m for the 55-m met towers). The ensuing ratio of cross-sectional area of the met towers to the cross-sectional area sampled by the radar (1.5 km) indicates the probability of interacting with (i.e., flying over or through the airspace occupied by) the met towers.

VERTICAL

The vertical-interaction probability is the probability that a bird seen on radar will be flying at an altitude low enough that it might pass through the airspace occupied by a met tower located somewhere on the radar screen. This probability is calculated from data on flight altitudes of Hawaiian Petrels and Newall's Shearwaters and from information on the height of the met towers. We used data from throughout the Hawaiian Islands (*n* = 2,010 birds; Cooper and Day, unpubl. data) to calculate the percentage of petrels/shearwaters with flight altitudes at or below the maximal height of the met towers (i.e., 18.6% ≤30 m, 29.7% ≤50 m, and 29.8% ≤55 m). We would have preferred to use flight-altitude data from the project area for the flight-altitude computations, but adequate sample sizes do not currently exist to do so.

FATALITY RATES

The annual estimated fatality rate is calculated as the product of: (1) the exposure rate (i.e., the number of birds that might fly within the airspace occupied by a met tower); (2) the fatality probability (i.e., the probability of collision with a portion of the met tower and dying while in the airspace occupied by the structure); and (3) the avoidance probability (i.e., the probability that a bird will detect and avoid entering the airspace containing the met tower). The annual fatality rate is generated as an estimate of the number of birds killed/yr as a result of collisions with the met tower, based on a 255-d breeding season for Hawaiian Petrels (Simons and Hodges 1998) and a 210-d breeding season for Newell's Shearwaters (Ainley et al. 1997b).

FATALITY PROBABILITY

The estimate of the fatality-probability portion of the fatality rate formula is derived as the product of: (1) the probability of dying if a bird collides with the tower frame/guy wires; and (2) the probability of colliding with the tower and associated guy wires if the bird enters the airspace occupied by these structures (i.e., are there gaps big enough for birds to fly through the structures without hitting any part of it). Because any collision with a met tower falls under the ESA definition of "take" we used an estimate of 100% for the first fatality-probability parameter. Note that the actual probability of fatality resulting from a collision is less than 100% because of the potential for a bird to hit a met-tower frame or guy wires and not die (e.g., a bird could brush a wingtip but avoid injury/death). In the met-tower design, the tower frame is a solid monopole or lattice tower, and the four sets of guy wires at five heights each occupy a substantial proportion of the total cone of airspace enclosed by the tower and guy wires, making it a low probability that a bird could fly though the space occupied by this tower without hitting some part of it. Hence, we conservatively estimated the probability of hitting the tower or guy wires if the bird enters the airspace at 100%.

AVOIDANCE PROBABILITY

The final parameter is the avoidance probability, which is the probability that a bird will see the met tower and change flight direction, flight altitude, or both so that it completely avoids flying through the space occupied by a met tower. Because avoidance probabilities are largely unknown, we present fatality estimates for a range of probabilities of collision avoidance by these birds by assuming that 90%, 95%, or 99% of all petrels or shearwaters flying near a met tower will see and avoid it. See discussion for explanation of avoidance rates used.

RESULTS

MOVEMENT RATES

We recorded 19 radar targets during summer 2008 (40.6 hrs sampling) and 4 radar targets during fall 2008 (38.9 hrs sampling) that fit our criteria for petrels and shearwaters. During summer we detected 7 of these targets at the upper station and 12 at the lower station and in the fall we detected all 4 targets at the lower station (Table 1). In the summer movement rates at both stations tended to be higher in the evening than in the morning; only one target out of the 19 was observed during the morning sampling period. In contrast, during the fall movement rates were higher in the morning; only one target out of four was observed during the evening sampling period. Mean movement rates during summer were 0.336 ± 0.12 targets/hr at the upper station and 0.576 ± 0.16 targets/hr at the lower station. Mean movement rates during fall were 0.0 targets/hr at the upper station and 0.188 ± 0.09 targets/hr at the lower station. The mean movement rate across both stations and all days was 0.456 ± 0.15 targets/hr in the summer and 0.094 ± 0.07 targets/hr in the fall. After adjusting our sampling results for hours of the night that we did not sample (i.e., non-peak periods), we estimated a mean movement rate across all sampling stations of 2.8 petrel-like targets/night during summer and 0.6 petrel-like targets/night during fall (Tables 2–4). We did not detect any petrel/shearwater targets during visual sampling.

EXPOSURE RATES

The exposure rate is calculated as the product of three variables: annual movement rate, horizontal-interaction probability, and vertical-interaction probability. As such, it is an estimate of the number of birds flying in the vicinity of the met tower (i.e., crossing the radar screen) that could fly in a horizontal location and at a low-enough altitude that they could interact with a tower. Based on our 2008 movement rate data, we estimate that ~348 Hawaiian Petrels and ~193 Newell's Shearwaters pass over the 1.5-km-radius radar sampling area in an average year (including birds at all altitudes; Tables 2–4). To generate annual exposure rates of birds exposed to each met tower (e.g., birds/tower/yr), we then multiplied the annual movement rate by the horizontal-interaction probability and the vertical-interaction probability. By applying those proportions to our data (and rounding up to the nearest whole number), we estimate that 1 Hawaiian Petrel and 1 Newell's Shearwater fly within the space occupied by each 30-m-high met tower in an average year (Tables 2 and 5), 2 Hawaiian Petrels and 1 Newell's Shearwater fly within the space occupied by each 50-m-high met tower in an average year (Tables 3 and 5), and 2 Hawaiian Petrels and 1 Newell's Shearwater fly within the space occupied by each 55-m-high met tower in an average year (Tables 4 and 5). Note that all these calculations are exposure rates and, thus, include an unknown proportion of birds that would detect and avoid the met towers. Hence, exposure rates estimate how many times/year a petrel or shearwater would be exposed to met towers and not necessarily the number that actually would collide with these structures.

FATALITY MODELING

The individual steps and estimates involved in calculating fatality rates are shown in Tables 2–4. We speculate that the proportions of birds that detect and avoid met towers is substantial (see Discussion), but only limited petrel- or shearwater-specific data are available to use for an estimate of these factors for marked/guyed met towers. Because it is necessary to estimate the fatality of petrels and shearwaters at the proposed and existing projects, however, we assumed that 90%, 95%, or 99% of all birds will be able to detect and avoid the met towers. If we also assume that 100% of the birds colliding with a met tower die (although see above), the ranges of annual fatalities are 0.004–0.039 Hawaiian Petrel/tower/yr and 0.002–0.022 Newell's Shearwaters/tower/year for the 30-m-high met tower; 0.012–0.115 Hawaiian Petrels/tower/yr and 0.006–0.064 Newell's Shearwaters/tower/yr for the 50-m-high met towers; and 0.014–0.138 Hawaiian Petrels/tower/yr and 0.008–0.077 Newell's Shearwaters/tower/yr for the 55-m-high met towers (Table 5). Looking at the cumulative annual fatalities, the annual fatality rate would be 0.046–0.462 Hawaiian Petrels/yr and 0.026–0.256 Newell's Shearwaters/yr for all four 50-m-high met towers combined, and 0.028–0.277 Hawaiian Petrels/yr and 0.015–0.153 Newell's Shearwaters/yr for both 55-m-high met towers combined (Table 5). We caution again, however, that the range of assumed avoidance rates of seabirds and met towers (90–99%) is not fully supported by empirical data at this time.

DISCUSSION

EXPOSURE RATES AND FATALITY ESTIMATES

We estimated that 0.4–1.4 Hawaiian Petrels would fly within the space occupied by each met tower per year (Table 5). For Newell's Shearwater we estimated that 0.2–0.8 individuals fly within the space occupied by each met tower per year. We used these estimated exposure rates as a starting

Table 2. Estimated average exposure rates and fatality rates of Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at guyed 30-m monopole met towers at the KWP I wind-energy site, Maui, Hawaii, based on radar data collected in July and October 2008. Values of particular importance are in boxes.

Variable/parameter for: 30-m NRG monopole met tower	HAPE	NESH
MOVEMENT RATE (MVR)		
A) Mean movement rate (targets/h)		
a1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.456	0.456
a2) Mean rate during nightly peak movement periods in fall based on October 2008 data (targets/h)	0.094	0.094
B) Number of hours of evening and morning peak period sampling	5.5	5.5
C) Mean number of targets during evening and morning peak movement periods		
c1) Spring/summer (a2*B)	2.508	2.508
c2) Fall (a1*B)	0.516	0.516
D) Mean proportion of birds moving during off-peak h of night	0.126	0.126
E) Seasonal movement rate (targets/night) = ((C*D)+ C)		
e1) Spring/summer	2.8	2.8
e2) Fall	0.6	0.6
F) Mean number of birds/target	1.05	1.05
G) Estimated proportion of each species	0.60	0.40
H) Daily movement rate (birds/day =E*F*G)		
h1) Spring/summer	1.78	1.19
h2) Fall	0.37	0.24
I) Fatality domain (days/year)		
i1) Spring/summer	180	150
i2) Fall	75	60
J) Annual movement rate (birds/year; = ((h1*i1) + (h2*i2)), rounded to next whole number)	348	193
HORIZONTAL INTERACTION PROBABILITY (IPH)		
K) Maximal cross-sectional area of tower and guys (side view = ((18.3m*30 m)/2)*2 = 549 m²	549.0	549.0
L) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m*30 m = 90,000 m²)	90000.000	90000.000
M) Average probability of radar target intersecting the met tower (= K/L, rounded to 8 decimal places)	0.00610000	0.00610000
VERTICAL INTERACTION PROBABILITY (IPV)		
N) Proportion of petrels flying ≤ tower height)	0.19	0.19
EXPOSURE RATE (ER = MVR*IPH*IPV)		
O) Daily exposure rate (birds/tower/day = H*M*N, rounded to 8 decimal places)		
o1) Spring/summer	0.00201860	0.00134573
o2) Fall	0.00041523	0.00027682
P) Annual exposure rate (birds/tower/year = J*M*N, rounded to 8 decimal places)	0.39484080	0.21897780
FATALITY PROBABILITY (MP)		
Q) Probability of striking tower or guys if in airspace	1.00	1.00
R) Probability of fatality if striking tower or guys[a]	1.00	1.00
S) Probability of fatality if an interaction (= Q*R)	1.00	1.00
FATALITY RATE (= ER*MP)		
T) Annual fatality rate with 90% exhibiting collision avoidance (birds/tower/year = P*S*0.10)	0.03948	0.02190
U) Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/year = P*S*0.05)	0.01974	0.01095
V) Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/year = P*S*0.01)	0.00395	0.00219

[1] Used 100% fatality probability due to ESA definition of "take", however actual probability of fatality with collision <100% (see methods).

Table 3. Estimated average exposure rates and fatality rates of Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at guyed 50-m monopole met towers at the proposed KWP II wind-energy site, Maui, Hawaii, based on radar data collected in July and October 2008. Values of particular importance are in boxes.

Variable/parameter for: 50-m NRG monopole met tower	HAPE	NESH
MOVEMENT RATE (MVR)		
A) Mean movement rate (targets/h)		
a1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.456	0.456
a2) Mean rate during nightly peak movement periods in fall based on October 2008 data (targets/h)	0.094	0.094
B) Number of hours of evening and morning peak period sampling	5.5	5.5
C) Mean number of targets during evening and morning peak movement periods		
c1) Spring/summer (a2*B)	2.508	2.508
c2) Fall (a1*B)	0.516	0.516
D) Mean proportion of birds moving during off-peak h of night	0.126	0.126
E) Seasonal movement rate (targets/night) = ((C*D)+ C)		
e1) Spring/summer	2.8	2.8
e2) Fall	0.6	0.6
F) Mean number of birds/target	1.05	1.05
G) Estimated proportion of each species	0.60	0.40
H) Daily movement rate (birds/day =E*F*G)		
h1) Spring/summer	1.78	1.19
h2) Fall	0.37	0.24
I) Fatality domain (days/year)		
i1) Spring/summer	180	150
i2) Fall	75	60
J) Annual movement rate (birds/year; = ((h1*i1) + (h2*i2)), rounded to next whole number)	348	193
HORIZONTAL INTERACTION PROBABILITY (IPH)		
K) Maximal cross-sectional area of tower and guys (side view = ((33.5m*50 m)/2)*2 = 1675 m²	1675.0	1675.0
L) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m*50 m = 150,000 m²)	150000.000	150000.000
M) Average probability of radar target intersecting the met tower (= K/L, rounded to 8 decimal places)	0.01116667	0.01116667
VERTICAL INTERACTION PROBABILITY (IPV)		
N) Proportion of petrels flying ≤ tower height)	0.30	0.30
EXPOSURE RATE (ER = MVR*IPH*IPV)		
O) Daily exposure rate (birds/tower/day = H*M*N, rounded to 8 decimal places)		
o1) Spring/summer	0.00590047	0.00393365
o2) Fall	0.00121374	0.00080916
P) Annual exposure rate (birds/tower/year = J*M*N, rounded to 8 decimal places)	1.15414200	0.64008450
FATALITY PROBABILITY (MP)		
Q) Probability of striking tower or guys if in airspace	1.00	1.00
R) Probability of fatality if striking tower or guys[1]	1.00	1.00
S) Probability of fatality if an interaction (= Q*R)	1.00	1.00
FATALITY RATE (= ER*MP)		
T) Annual fatality rate with 90% exhibiting collision avoidance (birds/tower/year = P*S*0.10)	0.11541	0.06401
U) Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/year = P*S*0.05)	0.05771	0.03200
V) Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/year = P*S*0.01)	0.01154	0.00640

[1] Used 100% fatality probability due to ESA definition of "take", however actual probability of fatality with collision <100% (see methods).

Table 4. Estimated average exposure rates and fatality rates of Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at guyed 55-m lattice met towers at the KWP I wind-energy site, Maui, Hawaii, based on radar data collected in July and October 2008. Values of particular importance are in boxes.

Variable/parameter for: 55-m NRG lattice met tower	HAPE	NESH
MOVEMENT RATE (MVR)		
A) Mean movement rate (targets/h)		
a1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.456	0.456
a2) Mean rate during nightly peak movement periods in fall based on October 2008 data (targets/h)	0.094	0.094
B) Number of hours of evening and morning peak period sampling	5.5	5.5
C) Mean number of targets during evening and morning peak movement periods		
c1) Spring/summer (a2*B)	2.508	2.508
c2) Fall (a1*B)	0.516	0.516
D) Mean proportion of birds moving during off-peak h of night	0.126	0.126
E) Seasonal movement rate (targets/night) = ((C*D)+ C)		
e1) Spring/summer	2.8	2.8
e2) Fall	0.6	0.6
F) Mean number of birds/target	1.05	1.05
G) Estimated proportion of each species	0.60	0.40
H) Daily movement rate (birds/day =E*F*G)		
h1) Spring/summer	1.78	1.19
h2) Fall	0.37	0.24
I) Fatality domain (days/year)		
i1) Spring/summer	180	150
i2) Fall	75	60
J) Annual movement rate (birds/year; = ((h1*i1) + (h2*i2)), rounded to next whole number)	348	193
HORIZONTAL INTERACTION PROBABILITY (IPH)		
K) Maximal cross-sectional area of tower and guys (side view = ((40m*55 m)/2)*2 = 2200 m²	2200.0	2200.0
L) Cross-sectional sampling area of radar at or below 55 m tower height (= 3000 m*55 m = 165,000 m²)	165000.000	165000.000
M) Average probability of radar target intersecting the met tower (= K/L, rounded to 8 decimal places)	0.01333333	0.01333333
VERTICAL INTERACTION PROBABILITY (IPV)		
N) Proportion of petrels flying ≤ tower height)	0.30	0.30
EXPOSURE RATE (ER = MVR*IPH*IPV)		
O) Daily exposure rate (birds/tower/day = H*M*N, rounded to 8 decimal places)		
o1) Spring/summer	0.00706906	0.00471270
o2) Fall	0.00145412	0.00096941
P) Annual exposure rate (birds/tower/year = J*M*N, rounded to 8 decimal places)	1.38272000	0.76685333
FATALITY PROBABILITY (MP)		
Q) Probability of striking tower or guys if in airspace	1.00	1.00
R) Probability of fatality if striking tower or guys[1]	1.00	1.00
S) Probability of fatality if an interaction (= Q*R)	1.00	1.00
FATALITY RATE (= ER*MP)		
T) Annual fatality rate with 90% exhibiting collision avoidance (birds/tower/year = P*S*0.10)	0.13827	0.07669
U) Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/year = P*S*0.05)	0.06914	0.03834
V) Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/year = P*S*0.01)	0.01383	0.00767

[1] Used 100% fatality probability due to ESA definition of "take", however actual probability of fatality with collision <100% (see methods).

Table 5. Summary of exposure rates, fatality rates, and cumulative fatality rates for Hawaiian Petrels (HAPE) and Newell's Shearwaters (NESH) at met towers at the existing KWP I wind energy site (30-m and 55-m met towers) and at met towers at the proposed KWP II wind energy site (50-m met towers), Maui, Hawaii, based on radar data collected in July (summer) and October (fall) 2008.

	Exposure rate/structure (birds/structure/yr)			Fatality rate/structure (birds/structure/yr)			Cumulative fatality rate (birds/yr)	
Structure type	HAPE	NESH	Avoidance Rate	HAPE	NESH	No. Structures	HAPE	NESH
30-m guyed met tower	0.395	0.219	0.90	0.039	0.022	1	0.039	0.022
			0.95	0.020	0.011	1	0.020	0.011
			0.99	0.004	0.002	1	0.004	0.002
50-m guyed met tower	1.154	0.640	0.90	0.115	0.064	4	0.462	0.256
			0.95	0.058	0.032	4	0.231	0.128
			0.99	0.012	0.006	4	0.046	0.026
55-m guyed met tower	1.383	0.767	0.90	0.138	0.077	2	0.277	0.153
			0.95	0.069	0.038	2	0.138	0.077
			0.99	0.014	0.008	2	0.028	0.015

point for developing a complete avian risk assessment; however, we emphasize that it currently is unknown whether bird use (i.e., exposure) and fatality at windfarm structures are strongly correlated. For example, Cooper and Day (1998) found no relationship between movement rates and fatality rates of Hawaiian Petrels and Newell's Shearwaters at powerlines on Kaua'i, indicating that other factors had a much greater effect on causing fatality than movement rates did. For example, other factors such as proximity to the ocean or poor weather could be more highly correlated with fatality rates than is bird abundance. As an example, collisions of Laysan Albatross with a large array of communication-tower antenna wires and guy wires adjacent to large, high-density albatross breeding colonies on Midway Atoll occurred at a far higher rate during periods of high winds, rain, and poor visibility: 838 (>25%) of the 2,901 birds killed during the 1.5-yr-long study were killed during two storms (Fisher 1966). To determine which factors are most relevant, future studies that collect concurrent data on movement rates, weather, and fatality rates would be useful to begin to determine whether movement rates and/or weather conditions can be used to predict the likelihood of petrel fatalities at met towers and other structures across the entire proposed windfarm.

In addition to these questions about the unknown relationships among abundance, weather, and fatality, few data are available on the proportion of petrels and shearwaters that do not collide with met towers because of collision-avoidance behavior (i.e., birds that completely alter their flight paths horizontally and/or vertically to avoid flying through the space occupied by a met tower). Clearly, the detection of met towers or other structures could result in collision-avoidance behavior by these birds and reduce the likelihood of collision. In addition, there appear to be differences between petrels and shearwaters in their ability to avoid obstacles. For example, Cooper and Day (1998) indicated that Hawaiian Petrels have flight characteristics that make them more adept at avoiding powerlines than Newell's Shearwaters, suggesting that Hawaiian Petrels might also be more likely to avoid collisions with other structures (e.g., met towers). These authors also suggested that the tendency for Hawaiian Petrels to approach and leave nesting colonies primarily during crepuscular periods enables these birds to see and avoid structures (e.g., met towers) more easily than Newell's Shearwaters that approach and leave nesting colonies primarily during nocturnal periods.

There is some collision-avoidance information available on petrels and shearwaters from earlier work that we conducted on Kaua'i (Cooper and Day 1998; Day and Cooper unpubl. data). In summary, those data suggest that the behavioral-avoidance rate of Hawaiian Petrels and Newell's Shearwaters near powerlines is high. For example, although we were unable to calculate an avoidance rate *per se* for the Kaua'i data, none (0%) of the 207 Hawaiian Petrels and none (0%) of the 392 Newell's Shearwaters that passed within 150 m of a powerline collided with it. These 599 birds probably include a substantial proportion of petrels and shearwaters that had flight paths that did not require a course correction to avoid the powerline; however, even when we examined only birds that flew within 25 m of a powerline, we found that 0 of 71 (0%) of all petrels and 0 of 113 (0%) shearwaters collided with the lines. Further, all 50 petrels and 34 shearwaters that were observed reacting to the lines were able to avoid collision (i.e., a 100% avoidance rate for those subsets of birds, if one assumes that without avoidance, all those birds would have collided with the lines).

There also is some information available on collision-avoidance of Hawaiian Petrels on Lana'i, where the behavior of petrels was studied as they approached large communication towers near the breeding colony (TetraTech 2008). In that study, all 20 (100%) of the Hawaiian Petrels seen on a collision-course toward communication towers exhibited avoidance behavior and avoided collision.

Additional data that might provide some insight on collision-avoidance behavior of petrels and shearwaters at windfarm structures (e.g., met towers and wind turbines) are available from other studies associated with the operational KWP I wind facility. There was 1 Hawaiian Petrel fatality and 0 Newell's Shearwater fatalities observed at the 20-turbines and three met towers in the first 33 months of operation (G. Spencer, First Wind, pers. comm.). Calculations using data for scavenging bias and searcher efficiency collected at the KWP I wind facility (First Wind 2008) indicate that the one observed fatality equates to a corrected direct take of ~1.2 Hawaiian Petrels/yr and 0.0 Newell's Shearwaters/yr (D. Cowan, First Wind, pers. comm.). Cooper and Day (2004b) modeled seabird fatality for the KWP I wind turbines, based on movement rates from radar studies at the site (Day and Cooper 1999; Cooper and Day 2004a, 2004b) and estimated that the combined annual fatality of Hawaiian Petrels and Newell's Shearwaters at the KWP I turbines would be ~3–18 birds/yr with a 50% avoidance rate, ~1–2 birds/yr with a 95% avoidance rate, and <1 bird/yr with a 99% avoidance rate. Thus, the fatality model using a 95% avoidance value was a closer fit with the measured fatality rates than the fatality model using a 50% avoidance rate.

Comparable avoidance data are not available for met towers, but the fact that no birds have been found killed at the three guyed met towers at KWP I (i.e., at the one 30-m tower and the two 55-m towers) during the first 3 years (33 months) of operation suggests that at least some petrels and shearwaters have been avoiding those structures: by assuming even a 90% avoidance rate, our models predicted that there would have been ~1 Hawaiian Petrel and ~1 Newell's Shearwater fatality/yr at the two 55-m met towers and one 30-m met tower at KWP I during each of the past 2 years (Table 5). In addition to the recent KWP I information, a fatality study was conducted at two ~40-m-high guyed met towers and four ~25-m-high guyed met towers at the KWP I site in May–July 1996 (Nishibayashi 1997). No petrels or shearwaters were found on any of the 26 searches of the six towers during this period (Nishibayashi 1997; Kaheawa Wind Power 2006), again suggesting avoidance of met towers.

In summary, the currently available data from Kaua'i, Lana'i, and Maui suggest that the avoidance rate of petrels and shearwaters at transmission lines and communications towers is high. Data from the fatality searches at turbines and met towers on Maui are more difficult to interpret (because they suggest high avoidance but are not a direct measure of avoidance), however those data also suggest that avoidance of those structures must be occurring since only one Hawaiian Petrel has been found during regular fatality searches of those structures over a two-year period. Thus, the overall body of evidence, while incomplete, is consistent with the notion that the average avoidance rate of met towers and other structures at windfarms is substantial and potentially is as high as 95%. The ability of Hawaiian Petrels and Newell's Shearwater to detect and avoid most objects under low-light conditions makes sense from a life-history standpoint, in that they forage extensively at night and are adept at flying through forests near their nests during those light conditions.

In addition to the limited data available for Hawaiian Petrels and Newell's Shearwaters, there is evidence that many other species of birds detect and avoid structures (e.g., met towers and wind turbines) during low-light conditions (Winkelman 1995, Dirksen et al. 1998, Desholm and Kahlert 2005, Desholm et al. 2006). For example, seaducks in Europe have been found to detect and avoid wind turbines >95% of the time (Desholm 2006). Further, natural anti-collision behavior (especially alteration of flight directions) is seen in migrating Common and King eiders (*Somateria mollissima* and *S. fischeri*) approaching human-made structures in the Beaufort Sea off of Alaska (Day et al. 2005) and in diving ducks approaching offshore windfarms in Europe (Dirksen et al. 1998). Collision-avoidance rates around wind turbines are high for Common Eiders in the daytime (Desholm and Kahlert 2005), gulls (*Larus* spp.) in the daytime (>99%; Painter et al. 1999, cited in Chamberlain et al. 2006), Golden Eagles (*Aquila chrysaetos*) in the daytime (>99%; Madders 2004, cited in Chamberlain et al. 2006), American Kestrels (*Falco sparverius*) in the daytime (87%, Whitfield and Band [in prep.], cited in Chamberlain et al. 2005), and passerines during both the day and night (>99%; Winkelman 1992, cited in Chamberlain et al. 2006).

We agree with others (Chamberlain et al. 2006, Fox et al. 2006) that species-specific, weather-specific, and site-specific avoidance data are needed in models to estimate fatality rates accurately. However, the currently available avoidance data from Kaua'i and Lana'i for

Hawaiian Petrels and Newell's Shearwaters and the petrel fatality data at KWP I wind turbines and met towers (one killed to date), while incomplete, is consistent with the notion that a substantial proportion of petrels detect and avoid wind turbines, marked met towers, communication towers, and powerlines under normal ranges of weather conditions and visibility (but note that avoidance rates could be lower under inclement conditions). Until further petrel- and shearwater-specific data on the relationship between exposure and fatality rates are available for structures at windfarms, we continue to provide a range of assumptions for avoidance rates in our fatality models (i.e., 90%, 95%, and 99% avoidance) along with a discussion of the body of evidence that, while incomplete at this time, is consistent with the notion that the average avoidance-rate value is substantial and potentially is as high as 95%. With a 95% assumption, the estimated average annual take at KWP I and KWP II met towers would be <0.1 Hawaiian Petrel/met tower/year and <0.1 Newell's Shearwaters/met tower/year.

There are additional factors that could affect our estimates of fatality, both in a positive and a negative direction. One factor that would have created a positive bias was the inclusion of targets that were not petrels or shearwaters. Our visual observations (especially during crepuscular periods, when we could use binoculars) probably helped to minimize the inclusion of non-target species, but it is possible that some of our radar targets were other fast-flying species that were active during the sampling period (e.g., Hawaiian Nene [*Branta sandvicensis*]). A second positive bias in our fatality model is our simplistic assumption that movement rates of seabirds did not fall as individual fatalities occurred (i.e., we assumed sampling with replacement for fatalities). Given the low movement rates observed in this study, it is likely that the fatality of just a single bird would substantially reduce the average nightly movement rates.

There also are factors that could create a negative bias in our fatality estimates. One example would be if targets were missed because they flew within radar shadows. Because the sampling stations provided good coverage of the surrounding area, we believe that the proportion of targets that was missed because they passed through the entire area of coverage of the study area within a radar shadow was minimal.

A factor that could affect the predictive value of our fatality estimates in either direction is interannual variation in seabird counts. The average hourly movement rate for the current study (summer = ~0.5 targets/hr, fall = ~0.1 targets/hr) and from summer 1999 (1.2 targets/hr; Day and Cooper 1999) and fall 2004 (1.0 targets/hr; Cooper and Day 2004a) suggests that rates are consistently very low at the KWP project areas and that interannual variation is minimal. Some caution in extrapolation of movement rates across years is still warranted, however, as there are examples of other sites with high interannual variation in counts, such as the three sites on Kaua'i where counts were ~100–300 birds/hr lower (~four times lower) in fall 1992 than in fall 1993; the lower counts in 1992 were attributed to the effects of Hurricane Iniki (Day and Cooper 1995). Oceanographic factors (e.g., El Niño–Southern Oscillation events) also vary among years and are known to affect the distribution, abundance, and reproduction of seabirds (e.g., Ainley et al. 1994, Oedekoven et al. 2001). Another factor that could cause interannual variation in counts in either direction is overall population increases or declines. For example, there was a ~60% decline in radar counts between 1993 and 1999–2001 that was attributed to population declines of Newell's Shearwaters (Day et al. 2003b).

CONCLUSIONS

We used our risk-assessment model to estimate the number of Hawaiian Petrels and Newall's Shearwaters that might be killed by collisions with met towers at the KWP I and KWP II facilities. The model is affected by several input variables; however, the collision-avoidance rate variable has a large effect on modeled estimates and is one of the most-poorly-understood variables at this time. The absence of adequate studies at other sites preclude determination of actual avoidance rates; however, there is a body of evidence for petrels at communication towers, transmission lines, and wind turbines that suggests that a high percentage of petrels detect and avoid structures (see above). In particular, fatality data from the Maui KWP I windfarm suggests that avoidance rates are high. We also suspect high rates of anti-collision behaviors because petrels must rely upon acute nocturnal vision for foraging and other flight activities under varying weather conditions and because many petrels travel to and from nest colonies while there is still light in the sky. In conclusion, we believe that the proportion of petrels that see and avoid met towers at KWP I and KWP II will be high, but emphasize that, until studies are conducted and data are available on avoidance behavior at marked met towers and wind turbines, the exact proportion will remain unknown. As a result, we have provided a range of assumptions for avoidance rates in our fatality models (i.e., 90%, 95%, and 99% avoidance rates) along with a discussion of the body of evidence that, while incomplete at this time, is consistent with the notion that the average avoidance-rate value is substantial and potentially is as high as 95%. With an assumption of 95% avoidance, the estimated average annual take at KWP I and KWP II met towers would be <0.1 Hawaiian Petrel/tower/year and <0.1 Newell's Shearwaters/tower/year.

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Appendix 5

Monitoring Hawaiian Hoary Bat Activity using
Acoustic Sensors at Kaheawa Pastures, West Maui: August – November, 2008

Introduction

KWP is conducting acoustic detector surveys to characterize Hawaiian hoary bat activity in the vicinity of the operating Kaheawa Pastures Wind Project (KWP) and the adjacent proposed Kaheawa Wind Project II (KWP). Objectives include: (1) documenting the presence of the species in the vicinity of the projects, (2) providing use data at KWP for comparison with ongoing post-construction fatality surveys in accordance with the project's Habitat Conservation Plan (HCP), and (3) providing use data in the proposed KWP II project area to help determine potential collision risk. This interim report provides a summary of survey methods and findings from inception in August 2008 to November 2008.

Methods

Anabat® SD1 bat detectors were used during the course of these surveys. These detectors are frequency division detectors that divide the high frequency that bats emit by a selected division ratio (in this case, 16) to create an audible call through the device that humans can hear. These detectors also record and store high frequency sounds onto Compact Flash (CF) storage cards as individual analog call files with appropriate date and time stamps that can then be viewed using specific software to determine the likely origin of each call (e.g., bat call sequence, high frequency noise or static, etc.). The Anabat call file structure also provide some ability to differentiate among species using each species' call sequence characteristics. However, considering that there is only one documented bat species in the Hawaiian Islands, all calls documented are likely to be the Hawaiian hoary bat.

Four Anabat (Titley Electronics, NSW, Australia) acoustic bat detector sampling stations were established at the KWP I and proposed KWP II sites on August 8, 2008 (Figure 1). Each station consisted of a detector attached to a double T-post platform and recorded on a 12-hour duty cycle (1800-0600) at a height of about five feet above ground level. The stations were located as follows:

- Station 1: KWP I Project Area, 2600' elevation, low grassland with scattered shrubs;
- Station 2: KWP I Project Area, 1900' elevation, mixed native/non-native shrubland;
- Station 3: KWP II Project Area, 2150' elevation, grassland with sparse native shrubs; and
- Station 4: KWP II Project Area, 2400' elevation, grassland with sparse native shrubs.

Bat detectors were moved to other locations, and new sampling stations established, on November 14, 2008 and this report provides the results of the surveys up to the November 14 re-deployment.

Detectors were visited every 7 to 12 days to check the overall status of the systems and download data from on-board CF storage cards. Recorded high frequency call files were sorted by night and visually inspected on a computer screen using Analook® software to determine the origin of sounds recorded into the file. Bats echolocate by sending out pulses of energy that are reflected off of surrounding structural features and potential prey. These pulses are clearly defined during visual analysis of the call files as bold lines with steep slopes relative to a frequency:time graph . High frequency noises (i.e. insects, rustling vegetation, and static), on the other hand, are depicted as broad, indistinct spots and bands across the same frequency:time graph. These latter types of files have no distinct, steep lines that represent the periodic pulses of energy emitted by bats. All call files that included only high frequency noise were removed from further data analysis during the first round of visual review.

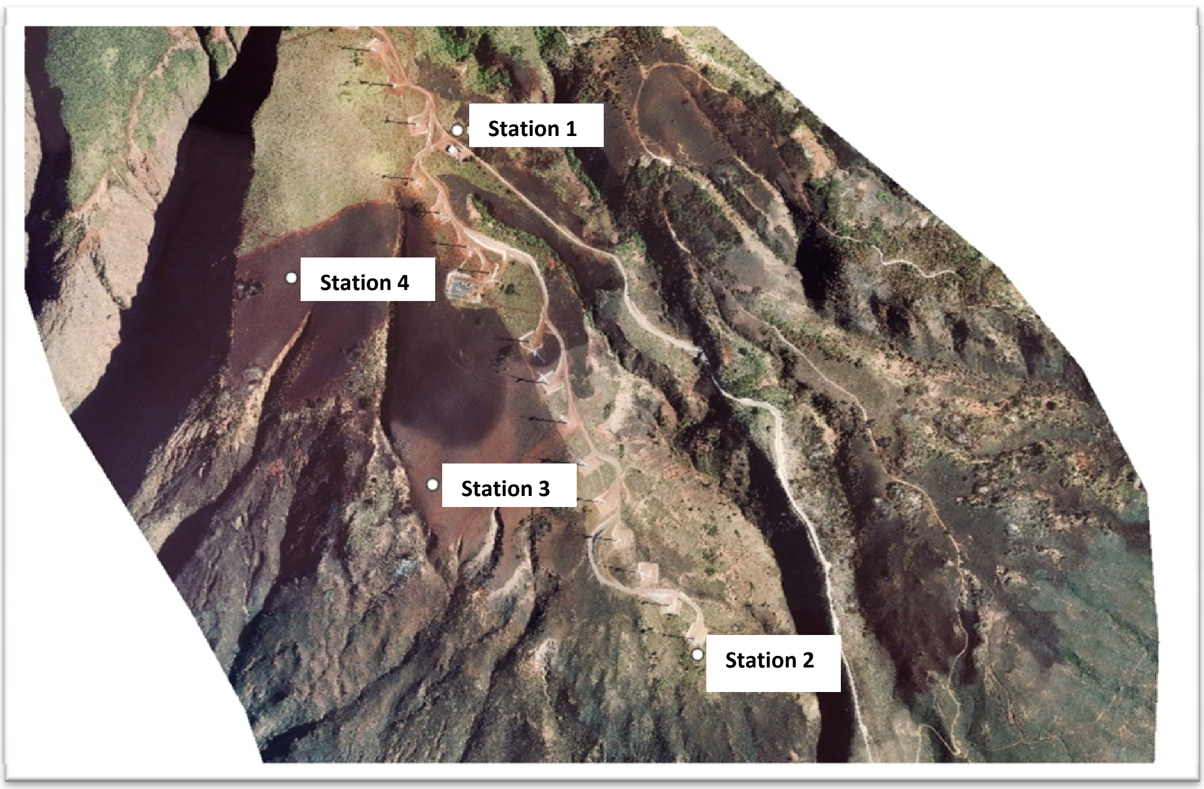

Figure 1. Survey Station Locations at Kaheawa Pastures, August – November 2008.

A recorded bat call file may contain one to dozens of these pulses, depending on how long the bat was present within range of a detector. These groups of pulses are called a call sequence. A standard practice in bat detector surveys is to provide an additional level of data quality by requiring a certain minimum number of call pulses within the recorded call sequence (Kunz *et al.* 2007). The standard practice that has developed for Hawaiian hoary bat surveys is to separate call files with only one or two pulses from call files with call sequences of 3 or more pulses. Call files that consist of sequences of 3 or more calls are considered to be qualified bat "passes", or the documented passing of one individual bat by that detector at the recorded date and time. Requiring the call sequences to conform to these data quality standards provides stronger data sets for comparison with other similarly reported surveys from the Hawaiian Islands (Bonaccorso, personal comm.). Appendix A provides examples of call sequence files classified as passes or not.

Once analysis of the recorded call files was completed, summary statistics of the sampling results were developed. These included the total recorded bat call files and bat passes for all detectors combined as well as for each individual detector. Detection rates were then calculated for each detector based on the number of bat passes and the number of nights during the deployment period during which the detectors were operating correctly (also known as detector-nights)[1]. Bat activity was also assessed relative to the hour of the night that call files and bat passes were recorded.

Results and Discussion

Some level of Hawaiian Hoary Bat activity was documented at each of the four sampling stations (Table 1). A total of fifteen call sequence files were recorded at all four stations over the three-month survey period, seven of which (from three of the detectors) were determined to be qualified bat passes. The range in the number of bat call sequences among the sampling stations ranged from one at Station 4 in the KWP II project area to seven at Station 1 in the KWP I project area. The range in the number of bat passes ranged from zero at Station 4 and three at Station 1. Overall, eleven call sequence files and five bat passes were documented from the KWP I project area while four call sequence files and two bat passes were documented from the KWP II project area. Detection rates also varied between the two project areas with 0.025 passes/detector-night in the KWP I project area and 0.011 passes/detector-night in the KWP II project area, despite similar levels of sampling effort.

Differences in detection rates between the sampling stations could be due to several factors. Habitat differences could account for differences in bat activity if, for example, prey availability would be greater over non-burned habitats sampled at the KWP I stations compared to the more recently burned areas sampled at KWP II. Additionally, the physical presence of the turbines themselves may act as a structural attractant if bats perceive the towers to be potential roost sites or productive foraging substrate. Since the KWP I stations represented the lowest and highest elevations of sampling but recorded the most number of call sequences and bat passes, it appears that altitude within the elevation gradient present within the project areas may not be affecting bat activity. However, the small sample size and data set from the investigations to-date does not provide a definitive explanation of the differences in activity documented thus far.

[1] Occasional periods of down-time can occur for individual detectors if, for example, battery voltage falls below the minimum necessary to operate a detector. Consequently, the number of operating nights for a detector could be less than the total number of nights it was deployed. Only operating nights are used to calculate the rate at which call files or bat passes are detected.

Table 1. Summary of Bat Detector Survey Data - West Maui Mountains, Fall 2008						
Station	Location	Survey Dates*	Number of Operating Nights	Number of Call Sequence Files	Qualifying Bat Passes**	Detection Rate (passes/detector-night)
1	KWP I	Aug 8 - Nov 14	99	7	3	0.030
2	KWP I	Aug 8 - Nov 14	99	4	2	0.020
3	KWP II	Aug 8 - Nov 14	81	3	2	0.025
4	KWP II	Aug 8 - Nov 14	99	1	0	0.000
		Subtotal KWP I	198	11	5	0.025
		Subtotal KWP II	180	4	2	0.011
		Overall Total	378	15	7	0.019

* Bat detector surveys are ongoing. Results represented here reflect all data recorded and analyzed to date.

** "Qualifying Bat Passes" represent recorded call sequence files that conform to data quality standards (such as number of call pulses and signal strength) commonly used to report detector data. As such, those call sequence files that do not conform to those standards are not included in the calculation of Detection Rates. Detection rates using 'passes' provides a more comparable data set with other studies.

Overall, very low levels of Hawaiian hoary bat activity were documented during the August to November sampling period. The detection rates from KWP I and II were much lower than similar studies performed by the USGS at Hakalau Forest National Wildlife Refuge (Bonaccorso, unpublished 2008) on the Big Island of Hawaii (0.634 calls/detector/night). Differences between detection rates at the KWP project areas and other sites surveyed could be due to habitat, overall population sizes and activity patterns between islands, and survey effort duration and timing.

The sampling results reported here are for the months of August through November, 2008. While this is a limited duration we did observe a concentration or pulse of activity within this time frame: twelve of the fifteen (80%) recorded call sequences and all seven (100%) of the qualified bat passes were documented between September 11 and October 22. This increased activity could be associated with one of several key life cycle stages. For example, female Hawaiian hoary bats are known to be lactating (possibly accompanied by dependent young) through August on Hawaii Island. This could represent a time period when females are foraging at greater intensities and during which a peak in detections might be expected using ultrasonic detectors. Little study has been directed at hoary bat distribution and seasonal movement patterns on Maui, however, and the lactating period for females could simply be later on Maui. Alternatively, the peak in activity we observed could be due to the dispersal of females and independent young after the completion of the pup-rearing period. In either case, the ongoing continuation of data collection in the two project areas will provide further insight into any seasonal activity patterns in the area.

Finally, the distribution of recorded call sequences throughout the night was assessed. In general, the greatest number of recorded call sequences was recorded during the first hour after sunset (Figure 2). This is typical of bat detector surveys, as the first part of the night is commonly cited as the most active time period for foraging bats. Due to the limited data set it is not possible to identify any definitive trends in nightly activity patterns. However, results from the ongoing field data collection will continue to be incorporated into the data set to examine temporal and seasonal activity patterns at the site.

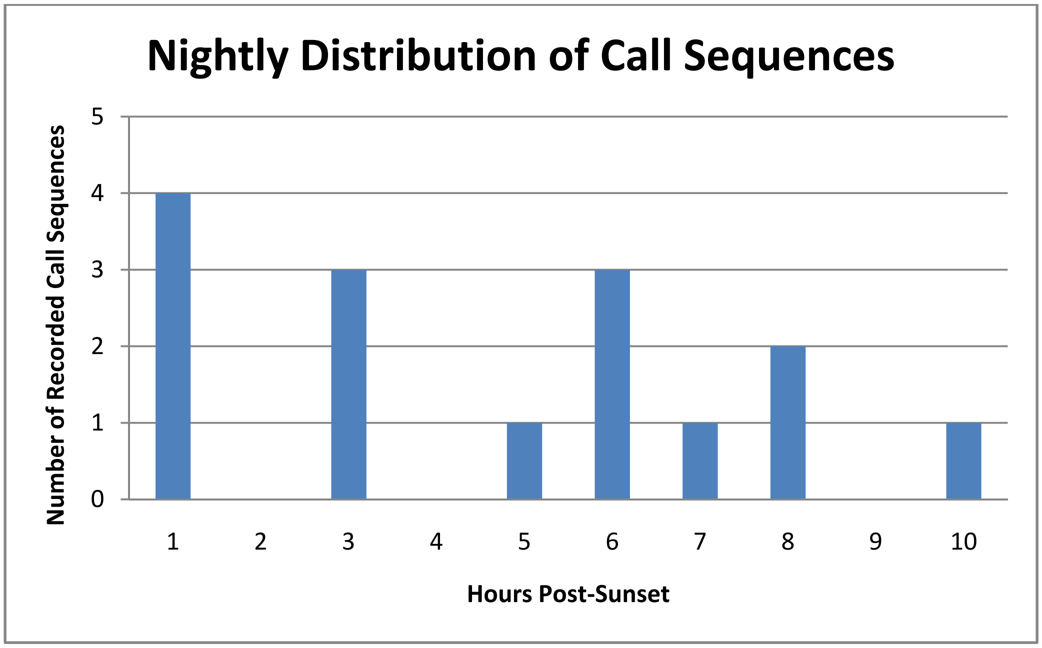

Figure 2. Distribution of all recorded call sequences based on hours after sunset.

Summary and Conclusions

The studies described above have provided preliminary but very useful information on the occurrence and potential activity patterns of Hawaiian hoary bats in West Maui and in the vicinity of an operational and proposed wind energy development. Overall, bat activity was low during the survey period relative to other acoustic detector surveys undertaken in the Hawaiian Islands.

The ongoing monitoring efforts will continue to provide further baseline information on whether there are seasonal or other detectable trends in the presence and activity of Hawaiian hoary bats observed at KWP and KWP II. In addition to in-house studies of bats being performed at the KWP and KWP II sites, First Wind hopes to work with other researchers and contribute substantially to what is known about the population ecology and requirements necessary to meet recovery goals for the species on Maui.

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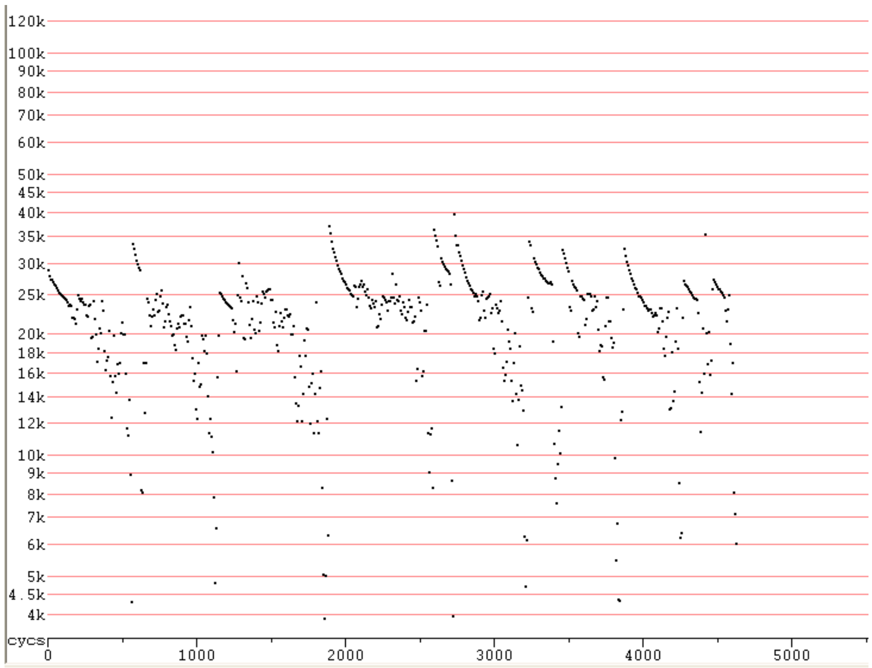
Appendix A

Examples of Recorded Call Sequence Files



Appendix A Figure 1. Example of a definitive call sequence classified as a bat pass. Note the large number of individual pulses and the defined depiction of each pulse.

Appendix A Figure 2. Example of a recorded call sequence that was not classified as a bat pass. Note that only two call pulses are included within the call sequence. While these are defined pulses of energy within the frequency range of the species there are too few to assure that they were emitted from a bat. Additionally, the individual pulses have a limited frequency range and do not include the taller, sweeping profile characteristic of the pulses in Figure 1.

Appendix 6

Wildlife Education and Observation Program

Purpose	To educate project employees and other on-site personnel in the observation, identification and treatment of wildlife
Approach	In conjunction with regular assigned duties, all personnel will: - attend wildlife education briefings conducted in cooperation with DOFAW and USFWS; - monitor wildlife activity while on the site; - identify key species when possible (Hawaiian Petrel, Newell's Shearwater, Nene and Hawaiian Hoary Bat); - document specific observations with the filing of a Wildlife Observation Form; - identify, report and handle any downed wildlife in accordance with the Downed Wildlife Protocol, including filing a Downed Wildlife Monitoring Form – Incidence Report; - respond and treat wildlife appropriately under all circumstances.
Notes	All personnel will avoid approaching any wildlife other than downed wildlife; avoid any behavior that would startle or harass any wildlife; and not feed any wildlife.

Descriptions and Photographs
Follow

Hawaiian Petrel	
Description	16 inches, 36-inch wingspan. Head, wings and tail are sooty-colored, contrasting with slightly paler back. Forehead and underparts are white; tail is short. Feet are bi-colored pink and black. Downy chicks are charcoal gray.
Voice	Distinctive call heard at breeding colonies is a repeated moaning "ooh-ah-ooh." At their burrows, birds also produce a variety of yaps, barks and squeals.
Habits	The Hawaiian Petrel is generally seen close to the main Hawaiian islands during breeding season; otherwise, it is a pelagic species. The flight is characterized by high, steeply-banked arcs and glides; the wings are long and narrow. Breeding extends from March to October. One white egg is laid within deep burrows or under rocks. Adults arrive in colonies well after dark. As the chicks develop, parental care becomes less frequent and adults leave the colony each year two to three weeks before the chicks. Adults feed on squid, fish and crustaceans, and pass food to chicks by regurgitation. Predation by introduced rats, cats and mongooses is a serious threat to this species.

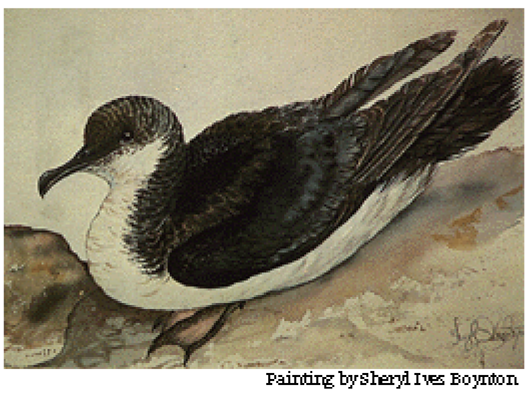
HNP/C. Hodges

HVNP/W. Banko

source: http://pacificislands.fws.gov/wesa/uau.html

source: http://www.birdinghawaii.co.uk/xHawaiianPetrel2.htm

Newell's Shearwater	
Description	12 – 14 inches, 30 – 35-inch wingspan. Black above and white below. The white extends from the throat to the black undertail coverts. Sharp contrast of dorsal/ventral color is more distinct than in larger, more common Wedge-tailed Shearwater. Bill, legs and toes are dark; webbing between toes is pink.
Voice	Around nesting colony, a variable, jackass-like braying and crow-like calling.
Habits	The flight of the Newell's Shearwater is characterized by rapid, stiff wingbeats and short glides. This species occurs in Hawaiian waters during the breeding season (April to November); it flies to nesting colonies only after dark, departing before dawn. Birds are highly vulnerable to predation by rats and cats. Many fledglings departing the colonies in late fall are attracted to urban lights and fall on highways or other brightly-lit areas.



source: http://pacificislands.fws.gov/wesa/ao.html

source: http://audubon2.org/webapp/watchlist/viewSpecies.jsp?id=141

source: http://www.birdinghawaii.co.uk/XNewells2.htm

Nene	
Description	22 – 26 inches, sexes similar. A medium-sized goose with black head and nape that contrasts with yellow-buff cheek. Neck is also buffy but with dark brown furrows. Heavily barred gray-brown above; lighter barrel below. Bill and partially-webbed feet are black. Adults weigh approximately 4 pounds, males are larger.
Voice	Call is a loud “haw” or “haw-ah,” resembling honking of the Canada Goose. Also gives a variety of muted calls, often resembling the “moo” of a cow.
Habits	Nene frequent scrubland, grassland, golf courses, and sparsely-vegetated slopes and, on Kaua`i, open lowland country. They feed on a variety of native and introduced plants. The breeding season extends from November to June. The nest is a down-lined bowl usually well-concealed under bushes; two to five white eggs are laid. Approximately 85 Nene have been released at Hanaula since 1995 as part of DOFAW’s propagation and recovery program. Predation by introduced mongooses and feral cats on eggs, goslings and brooding adults inhibits population increases.

source: http://www.aloha-hawaii.com/hawaii/nene

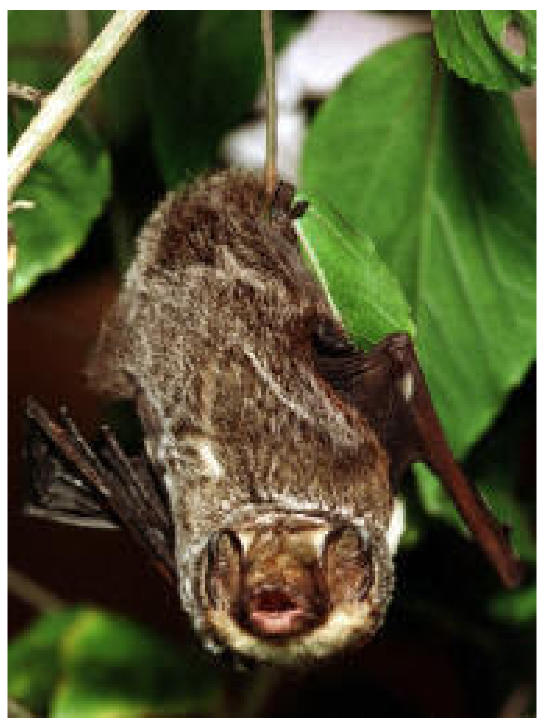
source: http://www.50states.com/bird/nene.htm

source: http://www.thewildones.org/Animals/nene.html

source: http://www.coffeetimes.com/nene.htm

Hawaiian Hoary Bat	
Description	Weighs 5 to 8 ounces, has a 10.5 – 13.5-inch wingspan. Females are larger than males. It has a heavy fur coat that is brown and gray, and ears tinged with white, giving it a frosted or "hoary" look.
Voice	Like most insectivorous bats, this bat emits high frequency (ultrasonic) echolocation calls that detect its flying prey. These calls generally range from 15 – 30 KHz. Their lower frequency social calls may be audible to humans. These low frequency “chirps” are used to warn other bats away from their feeding territory.
Habits	The Hawaiian Hoary Bat is nocturnal to crepuscular and eats insects. Little is known about its biology, distribution, or habitat use on the Hawaiian islands, though it is thought to be most abundant on the Big Island. It occurs primarily below 4,000 feet elevation, although it commonly is seen at 7,000 to 8,000 feet on Hawai`i and at 10,000 feet on Haleakala. On Maui, this bat is believed to primarily occur in moist, forested areas. In spite of this preference, though, it has been seen in Lahaina and near Mopua, both of which are dry, and on the dry, treeless crest of Haleakala. During the day, this bat roosts in a variety of tree species and occasionally in rock crevices and buildings; it even has been recorded hanging from wire fences on Kaua`i and has been seen leaving and entering caves and lava tubes on Hawai`i.

source: http://pacificislands.fws.gov/wesa/hrybatindex.html



source: http://www.honoluluzoo.org/hawaiian_bat.htm

SAMPLE

Wildlife Education and Observation Program
KWP II
Observation Form

Observer's Name:			**Date:**	
Temperature:	**Wind Direction:**	**Wind Speed:**	**Precipitation:**	**Cloud Cover:**

Species Observed	
Location	
Proximity to Turbine	
Approximate Altitude	
Direction Traveling	
Other Species in Area	
Comments	

Appendix 7

Life History Information on

Newell's Shearwater (*Puffinus auricularis newelli*),
Hawaiian Petrel (*Pterodroma sandwichensis*),
Hawaiian Goose (*Branta sandvicensis*)
and
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)

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Honolulu, HI 96813

1.0 INTRODUCTION

Demographic factors were used to assess indirect take and loss of productivity in section 6.0 (Potential Impacts) and 7.0 (Mitigation) of the HCP. Indirect take and loss of productivity are defined as follows:

> Indirect Take - These are individuals that suffer mortality as the result of a direct take of another individual. For example, the loss of a parent may also result in the loss of eggs or young.
>
> Loss of Productivity - Productivity can be assessed in terms of chicks or fledglings produced per breeding adult per year or the number of fledglings that survive to adulthood per breeding adult per year. When a direct take occurs, loss of productivity can occur between the time the direct take occurs and the time that mitigation is provided. Productivity may also be lost if a juvenile is used as a replacement for the take of a breeding age adult. Factors that need to be taken into consideration when accounting for loss of productivity include demographic factors such as the age and sex of the individuals taken, the time of year the take occurs, and the type of mitigation provided.

Demographic factors for each species covered by the HCP were determined using existing literature. Preference was given to life history information available from Hawai'i, followed by information available for the same species on the North American continent or other areas of the world. If specific information was lacking for any species, life history information for a closely related species was used as a surrogate.

The life history information for the Newell's shearwater (*Puffinus auricularis newelli*), Hawaiian petrel (*Pterodroma sandwichensis*), Hawaiian goose (*Branta sandvicensis*) and Hawaiian hoary bat (*Lasiurus cinereus semotus*) follow in the sections below.

1.1 Seabirds

1.1.1 Newell's Shearwater

The following demographic factors and assumptions (from Ainley et al. 1997 and as otherwise noted) were used to assess indirect take and loss of productivity of the Newell's shearwater.

Breeding season: The breeding season lasts from June to October each year.

Age at First Breeding: Assumed age 6.

Adults Breeding/Year: On the basis of estimates made by Telfer (1986), incidence of non-breeding is high for Newell's Shearwater on Kaua'i. Only 46% of pairs that actively use a burrow actually breed in a given year (range 30–62 %, *n* = 5 yr, 36– 47 burrows monitored/yr).

Reproductive Success: 66.0% ± 6.4 SD (range 49–75) of nests in which eggs are laid fledge young. Manx Shearwater populations have similar fledging rates (Brooke 1990). For the purposes of the HCP, a 70% average fledging rate is assumed.

Survival: Annual adult survivorship of Newell's Shearwater was estimated to be 0.904 ± 0.017 SE, on the basis of allometric equation relating survivorship to body mass in procellariiforms. This figure approximates that estimated for Manx Shearwater by more conventional means (Brooke 1990). For the purposes of the HCP, it is assumed that 50% of fledged young survive to breeding age.

Number of Broods: One per year.

Clutch Size: One.

Relative Productivity of Males vs. Females: Relative productivity of males and females is assumed to be similar, as with the Hawaiian petrel described below. For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

1.1.2 Hawaiian Petrel

The following demographic factors and assumptions (from Simons and Hodges 1998 and as otherwise noted) were used to assess indirect take and loss of productivity of the Hawaiian petrel:

Breeding season: The breeding season lasts from May to October each year

Age at First Breeding: Unknown, but population data suggests breeding starts at age 5-6. Age 5 is assumed for purposes of estimating indirect take and lost productivity.

Adults Breeding/Year: Estimated at 89%.

Reproductive Success: Estimates of annual reproductive success (chicks fledged/eggs laid) at Haleakala, Maui from 1979–1981 (Simons 1985) and 1993 (Hodges 1994) averaged 63.4 % ± 16.0 SD (range 38–82, n = 128). For the purpose of the HCP, the average annual reproductive success of 70% is assumed.

Survival: In an analysis of life history by Simons (1984), survival to breeding age was estimated to be 27%. For the purpose of the HCP, it is assumed that 30% of fledged young survive to breeding age. Yearly adult survivorship was estimated to be 93%.

Number of Broods: One per year.

Clutch Size: One.

Relative Productivity of Males vs. Females: Breeding Hawaiian petrels are apparently monogamous and show a high degree of mate fidelity over subsequent years. Pairs may exhibit courtship behavior that may last one or more seasons prior to breeding. Thus the loss of a male could cause a breeding hiatus for a female even if in pre-breeding condition. Both males and females incubate eggs and provide food for nestlings. For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

Sex Ratio: Similar adult male and female survival rates in related species (Warham 1996) suggests a balanced sex ratio, but no published data is available.

1.2 Hawaiian Goose

Adjustments to the take of Nene were developed based on the following demographic factors and assumptions (from Banko et al. 1999 and USFWS 2004 and as otherwise noted):

Breeding season: The nēnē has an extended breeding season with eggs reported from all months except May, June, and July, although the majority of birds in the wild nest during the rainy (winter) season between October and March.

Age at First Breeding: Female nēnē mature at age three and males at age two. For the purposes of this HCP, it is assumed that both genders of nēnē mature at age three.

Adults Breeding/Year: Estimated at 60%.

Clutch Size: A clutch typically contains 3 to 5 eggs (mean 3.13 ± 1.07, range 1 to 6, n = 552 nests in the wild

Number of Broods: One per year.

Reproductive Success: During 4 seasons (1978–1981) mostly in highland habitat on Hawai'i and Maui, eggs hatched in at least 36 % (n=50) of 140 observed breeding attempts, and goslings fledged in 7 % (n=10; Banko 1992). During 1994– 1996 at Hawai'i Volcanoes National Park, eggs hatched in 58 % (21) of 36 nests with known outcomes, resulting in 42 goslings (2.0 goslings/successful pair) and 6 fledglings (0.29 fledgling/successful pair; Hu 1998). For the purposes of this HCP, it is assumed that adults have an average of 0.3 fledglings per pair.

Survival to breeding age: The mortality rate of captive-reared released goslings to Year 1 was reported to be 16.8% for females and 3% for males. For the purposes of this HCP, a conservative annual mortality rate of 20% is assumed for both genders of geese and this rate is assumed constant through maturity (age three).

Relative Productivity of Males vs. Females: Nēnē are highly territorial during the breeding season and males are likely to be defending nesting territories while the females are incubating. Family groups often forage together. For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

1.3 Hawaiian Hoary Bat

Little life history information exists for the hoary bat (*Lasiurus cinereus cinereus*) found on continental America. Because these bats are migratory, do not hibernate and are not colonial, they are difficult to study. Even less life history information is available for the Hawaiian hoary bat. Hence, adjustments to the take of the Hawaiian hoary bat to account for lost productivity were developed based on the following demographic factors and assumptions using information from the hoary bat from continental America or other bat species when necessary:

Breeding Season: The pregnancy and lactating period for the female Hawaiian hoary bat occurs from April to Augustr each year. The breeding lasts approximately four months, with a three month gestation period followed by parental care of one month (NatureServe 2008).

Age at First Breeding: Hoary bats on the continental US breed at age one (Gannon 2003, Koehler and Barclay 2000)

Adults Breeding/Year: Estimated at 100% for colonial bats (Gannon 2003), no data available for the hoary bat. Adults beeding/year is assumed to be 100 % for the Hawaiian hoary bat for purposes of this HCP.

Reproductive Success: A study following young of the hoary bat in Manitoba, Canada records that 23 out of 25 young fledged, resulting in a reproductive success of 92% (Koehler and Barclay 2000). Reproductive success is typically high for bats as they have a life history strategy where they have few young, low reproductive rates and are long lived compared to mammals of equivalent size (Kunz et al. 2005).

Survival to breeding age: No data exists for the Hawaiian hoary bat or the hoary bat on the American continent. However, survival is low for female little brown bats (*Myotis lucifugus* 20.4-47.2%) and female big brown bats (*Eptesicus fuscus,* 10.5-31.9%, Humphrey 1982). Survival rates of Hawaiian hoary bats probably approximate those of the big brown bat more closely than the little brown bat, given that they similar life history strategies such foliage roosting and the ability to commonly have two young at a time. The survival rate of Hawaiian hoary bats is estimated to be 30%.

Number of Broods: One per year.

Litter Size: Both Bogan (1972) and Koehler and Barclay (2000) in separate observations record that 6 females located before parturation gave birth to a total of 11 young, resulting in an average litter size of 1.83.

Relative Productivity of Males vs. Females: Male hoary bats only contribute sperm to the breeding process. Females are solely responsible caring and feeding the young till fledging. For the purposes of estimating inidirect take, it is assumed that males contribute nothing to indirect take and females 100%.

Sex Ratio: Sex ratios of Hawaiian hoary bats inferred from samples obtained during different seasons indicate that during the pre-pregnancy and breeding season (April to August), sex ratios in the lowlands are approximately 1:1. During the post-lactation period (September to December) the sex ratio of females to males in the lowlands increases to 4:1 (Menard 2001).

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Appendix 8

Funding Matrix for KWP II (pending)

Appendix 9

POST – FIRE BOTANICAL SURVEY AND ASSESSMENT

for

KAHEAWA WIND POWER II

UKUMEHAME, MAUI, HAWAII

by

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January 2009

Prepared for:
Kaheawa Windpower, LLC

INTRODUCTION

The Kaheawa Wind Power II Project is situated about ¼ mile west of an existing line of functioning wind turbines in Kaheawa Pasture, Ukumehame, West Maui TMK (2) 4-8-01:01 por. (see attached map). The work consists of a botanical followup survey of a proposed wind turbine project area with a special focus on assessing changes in the vegetation resulting from a wild fire that burned the area in 2006. Field work was conducted in January, 2009.

SITE DESCRIPTION

The project area lies on approximately 450 acres of sloping ridge land that is between 1,500 feet and 3,100 feet elevation. Ridge tops are smooth with relatively deep soil. Small to moderate sized gullies cut through the south and western sides of the ridge and are rough and rocky as they run down slope. Vegetation mostly consists of low wind blown grasses and shrubs with occasional patches of small trees. Annual rainfall ranges from about 20 inches at the bottom up to 50 inches at the top with the bulk falling during the winter months (Armstrong, 1983).

SURVEY OBJECTIVES

This report summarizes a botanical survey of the Kaheawa Wind Power II project area which was completed in January, 2009. The objectives of the survey were to:

1. Document what plant species occur within the project area.
2. Document the status and abundance of each species.
3. Determine the presence of any native plant species and particularly any that are Federally listed as Threatened or Endangered under the Endangered Species Act (USFWS,1999). If such occur, identify what features of the habitat may be essential for these species.
4. Assess the changes in the vegetation that may have occurred since a wild fire swept through this area in 2006.

SURVEY METHODS

The botanical survey consisted of a series of sweeps across the different elevations of the property that ensured complete coverage of the area. Areas most likely to harbor native species such as rocky outcrops and gulch slopes were more intensively examined. Binoculars were used to scan less accessible locations. Notes were made on plant species, distribution, abundance, terrain and substrate.

DESCRIPTION OF THE VEGETATION

The vegetation was predominantly a grassland both in character and in number of species. Most abundant was molasses grass (*Melinis minutiflora*). Also common were Natal redtop (*Melinis repens*), pitted beardgrass (*Bothriochloa pertusa*) and buffelgrass (*Cenchrus ciliaris*). Interspersed within the grass land were a number of common shrubs, herbs, one fern and one tree species. They include: inikö (*Indigofera suffruticosa*), ‘ilima (*Sida fallax*), ‘uhaloa (*Waltheria indica*), ‘ūlei (*Osteomeles anthyllidifolia*), fireweed (*Senecio madagascariensis*), partridge pea (*Chamaecrista nictitans*), narrow-leaved plantain (*Plantago lanceolata*), kilau fern (*Pteridium aquilinum* var. *decompositum*) and common ironwood (*Casuarina equisetifolia*). The remaining 73 plant species were uncommon or rare of occurrence.

Twenty native Hawaiian species were found in the project area. They include: kilau fern, ‘ilima, ‘uhaloa, ‘ūlei, (*Carex wahuensis*) no common name, (*Trisetum inaequale*) no common name, ko’oko’olau (*Bidens mauiensis*), ko’oko’olau (*Bidens micrantha*), nehe (*Melanthera lavarum*), Hawaiian moonflower (*Ipomoea tuboides*), ‘akoko (*Chamaesyce celastroides* var *amplectens*), ‘öhi’a (*Metrosideros polymorpha*), ‘iliahi alo’e (*Santalum ellipticum*), ‘akia (*Wikstroemia oahuensis*), pili grass (*Heteropogon contortus*), koali awahia (*Ipomoea indica*), pukiawe (*Leptecophylla tameiameiae*), huehue (*Cocculus orbiculatus*), naio (*Myoporum sandwicense*) and ‘a’ali’i (*Dodonaea viscosa*). The native plant species are spread throughout the project area, mixed among the grasses, but are less prevalent at the lower, drier parts of the property. There is, however, one pocket of predominantly native shrubland on the western edge of the project area on an eroded rocky ridge between 2,000 ft. and 2,400 ft. elevation.

DISCUSSION AND RECOMMENDATIONS

At the time of the first botanical survey of this project area in October of 2006, the vegetation was just beginning to recover from a fire that had burned 80% of the area. What we are seeing today is the regrowth of just over two years on an area that was basically bare, blackened ground. Only about 40 acres at the top of the present project area escaped the 2006 burn and is representative of unburned vegetation.

What is growing at the top of the project in the unburned area is basically the same as what it was before 2006, a diverse native shrubland mixed with grass. There has been a noticeable increase in molasses grass, but it is in small scattered clumps. Molasses grass along with the other grass species occupies about 20% of the vegetation cover.

The burned area between 2,300 feet and 2,900 feet elevation was regrown with a dramatically noticeable increase in grass species and a decrease in native shrubs. Molasses grass forms a dense, nearly monotypic growth over most of this area with an estimated frequency of 80% cover.

The burned area between 1,900 feet and 2,300 feet elevation has regrown with a similarly dramatic increase in grass species. This grassland is a mixture of molasses grass and Natal redtop in fairly even proportions with an estimated frequency of 80% cover. The eroded ridge with native shrubland sustained only a light burn due to the scarcity of fuels and has recovered with little loss of species or cover.

The lowest part of the project area between 1,500 feet and 1,900 feet elevation has been an open grassland for a long time. Since the 2006 fir it has come back in essentially the same condition. Dominant grasses are pitted beardgrass and buffelgrass with an estimated frequency of nearly 90% cover.

The Ukumehame lands, of which the Kaheawa Wind Power II project area is a small part, had been grazed by cattle for well over 100 years. During this period much of the native vegetation had been converted to non-native grasslands. Cattle grazing, has been discontinued in this area for over ten years now and this has had a profound effect on the vegetation. First, without cattle grazing, the grasses have grown up creating a dense fuel load. During this period there have been three large and devastating fires unlike any that have been experienced in recent memory. Following each fire, regrowth has been with increasing amounts of grass. This encourages a perpetuating cycle of fires as long as there are risks of fire starts. The two grass species which contribute most to fuel loading are molasses grass in the damper areas above 2,000 feet, and buffelgrass in the drier areas below 2,000 feet. Both of these species are considered to be fire adapted grasses that thrive and multiply with periodic burning because they replace or outcompete species that suffer from the effects of burning. This cycle will likely continue unless fuel hazards can be reduced or risks of fire starts can be minimized, or both.

A total of 86 plant species were recorded during the course of the botanical survey. Of these 20 were endemic or indigenous to the Hawaiian Islands. None of these were Federally listed as Threatened or Endangered under the Endangered Species Act. None were candidates for such status either. Only one, (*Trisetum inaequale*) is somewhat rare, having a limited distribution on West Maui and Lana'i. All of the rest of the native species occur on more than one or on several islands.

The Endangered species in this region on southern West Maui occur in remnant forests in the gulches of Papalaua, Manawainui and Pohakea and on ridge top shrub forests, all mauka of the present project. These species were addressed during the first Kaheawa project. The present project is further from these resources. Concerns would be similar, as the planned wind turbines and their placement would be nearly the same.

PLANT SPECIES LIST

Following is a checklist of all those vascular plant species inventoried during the field studies. Plant families are arranged alphabetically within three groups: Ferns, Monocots and Dicots. Taxonomy and nomenclature of the ferns are in accordance with Palmer (2003) and the flowering plants are in accordance with Wagner et al. (1999) and Staples and Herbst (2005).

For each species, the following information is provided:

1. Scientific name with author citation.

2. Common English or Hawaiian name.

3. Bio-geographical status. The following symbols are used:

   endemic = native only to the Hawaiian Islands; not naturally occurring anywhere else in the world.
   indigenous = native to the Hawaiian Islands and also to one or more other geographic area(s).
   Polynesian introduction = plants introduced to Hawai'i in the course of Polynesian migrations and prior to western contact.
   non-native = all those plants brought to the islands intentionally or accidentally after western contact.

4. Abundance of each species within the project area:

   abundant = forming a major part of the vegetation within the project area.
   common = widely scattered throughout the area or locally abundant within a portion of it.
   uncommon = scattered sparsely throughout the area or occurring in a few small patches.
   rare = only a few isolated individuals within the project area.

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
FERNS			
DENNSTAEDTIACEAE (Bracken Family)			
Pteridium aquilinum (L.) Kuhn. var. *decompositum* (Gaudich.) R.M. Tryon	*kilau*	endemic	common
PTERIDACEAE (Brake Fern Family)			
Pityrogramma austroamericana Domin.	gold fern	non-native	rare
MONOCOTS			
CYPERACEAE (Sedge Family)			
Carex wahuensis C.A. Mey. subsp. *wahuensis*	-----------------	endemic	uncommon
POACEAE (Grass Family)			

Andropogon virginicus L.	broomsedge	non-native	uncommon
Bothriochloa barbinodis (Lag.) Herter	fuzzy top	non-native	rare
Bothriochloa pertusa (L.) A. Camus	pitted beardgrass	non-native	common
*Cenchrus ciliaris*L.	buffelgrass	non-native	common
Cynodon dactylon (L.) Pers.	Bermuda grass	non-native	rare
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	non-native	rare
Digitaria insularis (L.) Mez ex Ekman	sourgrass	non-native	rare
Heteropogon contortus (L.) P. Beauv. ex Roem.&Schult.	pili grass	indigenous	rare
Hyparrhenia rufa (Nees.) Stapf	thatching grass	non-native	rare
Melinis minutiflora P. Beauv.	molasses grass	non-native	abundant
Melinis repens (Willd.) Zizka	Natal redtop	non-native	common
*Panicum maximum*Jacq.	Guinea grass	non-native	rare
Paspalum conjugatum Bergius	Hilo grass	non-native	rare
*Paspalum dilatatum*Poir.	Dallis grass	non-native	rare
Pennisetum clandestinum Chiov.	Kikuyu grass	non-native	uncommon
Rhytidosperma pilosum (R.Br.) Connor & Edgar	hairy oatgrass	non-native	rare

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Setaria parviflora (Poir.) Kerguelen	yellow foxtail	non-native	rare
Setaria verticillata(L.) P. Beauv.	bristly foxtail	non-native	rare
Sporobolus africanus (Poir.) Robyns & Tournay	smutgrass	non-native	uncommon
*Trisetum inaequale*Whitney	-----------------	endemic	rare
DICOTS			
ANACARDIACEAE (Mango Family)			
Schinus terebinthifolius Raddi	Christmas berry	non-native	uncommon
APOCYNACEAE (Dogbane Family)			
Stapelia gigantea N.E. Brown	Zulu giant	non-native	rare
ASTERACEAE (Sunflower Family)			
Acanthospermum australe (Loefl.) Kuntze	spiny bur	non-native	rare
Ageratina adenophora (Spreng.) R.King & H.Robinson	Maui pamakani	non-native	rare

*Bidens cynapiifolia*Kunth	------------------------	non-native	rare
Bidens mauiensis (A.Gray) Sherff	ko'oko'olau	endemic	rare
*Bidens micrantha*Gaud.subsp. *micrantha*	ko'oko'olau	endemic	uncommon
Bidens pilosa L.	Spanish needle	non-native	rare
Conyza bonariensis (L.) Cronq.	hairy horseweed	non-native	uncommon
Conyza canadensis (L.) Cronq.	horseweed	non-native	rare
*Emilia fosbergii*Nicolson	red pualele	non-native	rare
Erigeron karvinskianus DC.	daisy fleabane	non-native	uncommon
*Galinsoga parviflora*Cav.	------------------	non-native	rare
Heterotheca grandiflora Nutt.	telegraph weed	non-native	rare
*Hypochoeris radicata*L.	gosmore	non-native	rare
Melanthera lavarum (Gaud.) Wagner & Rob.	nehe	endemic	rare
Senecio madagascariensis Poir.	fire weed	non-native	common
Sonchus oleraceus L.	pualele	non-native	uncommon

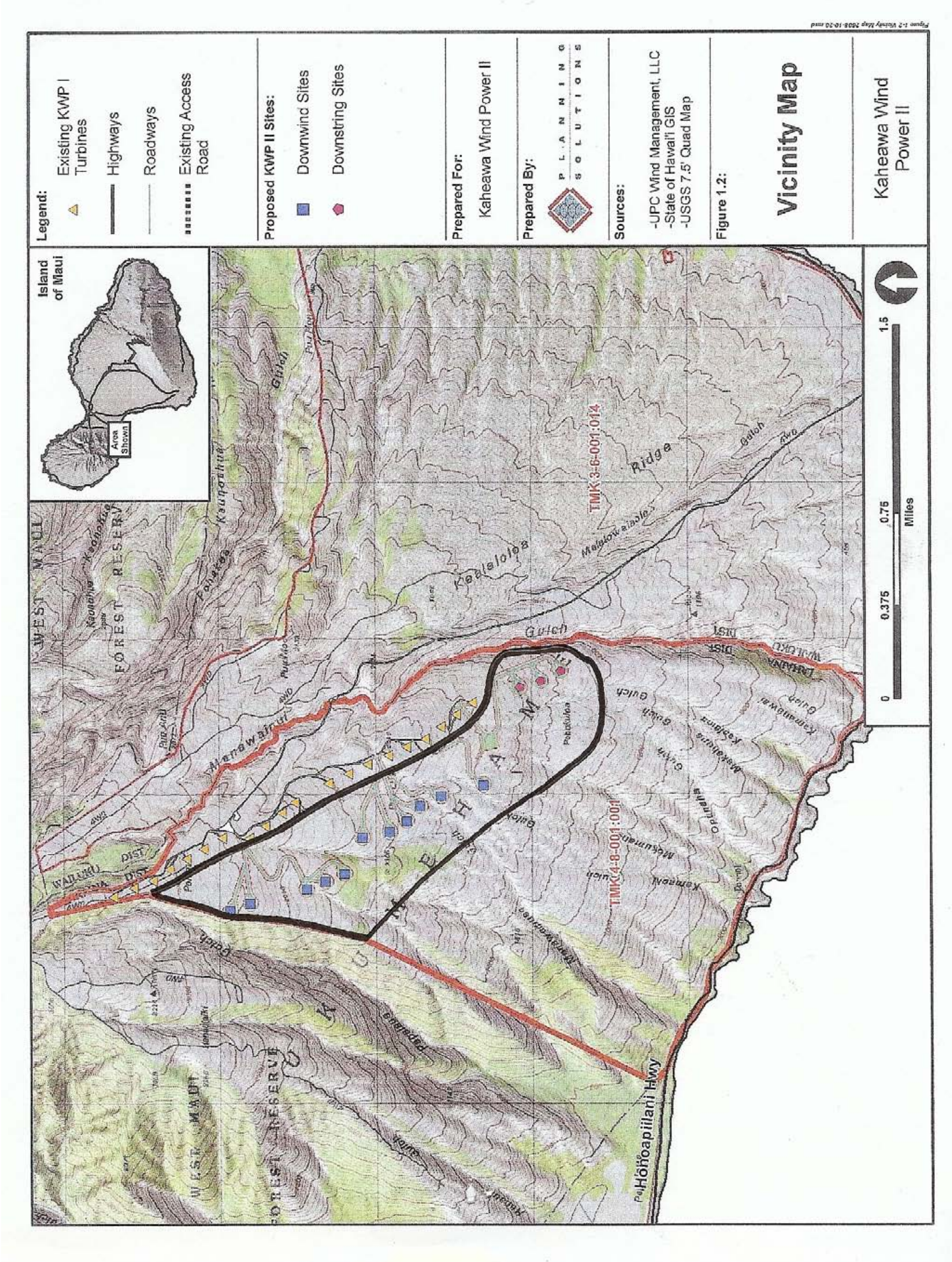
SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
*Tridax procumbens*L.	coat buttons	non-native	rare
Zinnia peruviana (L.) L.	zinnia	non-native	rare
BRASSICACEAE (Mustard Family)			
Sisymbrium officinale (L.) Scop.	hedge mustard	non-native	rare
CACTACEAE (Cactus Family)			
Opuntia ficus-indica (L.) Mill	panini	non-native	rare
CASUARINACEAE (She-oak Family)			
Casuarina equisetifolia L.	common ironwood	non-native	common
Casuarina glauca Siebold ex Spreng.	longleaf ironwood	non-native	rare
CONVOLVULACEAE (Morning Glory Family)			
Ipomoea indica (J. Burm.) Merr.	koali awahia	indigenous	uncommon
Ipomoea tuboides Degener & Ooststr.	Hawaiian moon flower	endemic	rare
ERICACEAE (Heath Family)			
Leptecophylla tameiameiae (Cham. & Schlect.) C.M. Weiller	pukiawe	indigenous	uncommon

EUPHORBIACEAE (Spurge Family)			
Chamaesyce celastroides (Boiss.) Croizat & Degener var. amplectens (Sherff) Degener & I.Degener	'akoko	endemic	rare
FABACEAE (Pea Family)			
Acacia farnesiana(L.) Willd.	klu	non-native	uncommon
Chamaecrista nictitans (L.) Moench	partridge pea	non-native	common
*Crotalaria pallida*Aiton	smooth rattlepod	non-native	rare
Crotalaria retusa L.	------------------	non-native	rare
Desmanthus pernambucanus (L.) Thellung	slender mimosa	non-native	uncommon
Desmanthus incanum DC.	kaimi clover	non-native	rare
*Desmodium sandwicense*E. Mey.	Spanish clover	non-native	rare
Indigofera suffruticosa Mill.	inikö	non-native	common
Leucaena leucocephala(Lam.) de Wit	koa haole	non-native	uncommon

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Macroptilium lathyroides (L.) Urb	wild bean	non-native	rare
Prosopis pallida(Humb.&Bonpl. ex Willd.) Kunth	kiawe	non-native	rare
LAMIACEAE (Mint Family)			
Salvia coccinea B. Juss. ex Murray	scarlet sage	non-native	rare
MALVACEAE (Mallow Family)			
Abutilon grandifolium(Willd.) Sw.	hairy abutilon	non-native	rare
*Malva parviflora*L.	cheese weed	non-native	rare
Malvastrum coromandelianum(L.) Garcke	false mallow	non-native	rare
Sida fallax Walp	'ilima	indigenous	common
Triumfetta semitriloba Jacq.	Sacramento bur	non-native	rare
Waltheria indica L.	'uhaloa	indigenous	common
MENISPERMACEAE (Moonseed Family)			
Cocculus orbiculatus (L.) DC.	huehue	indigenous	uncommon
MYOPORACEAE (Myoporum Family)			
Myoporum sandwicense A. Gray	naio	indigenous	rare
MYRTACEAE (Myrtle Family)			

Metrosideros polymorpha Gaud.	'ōhi'a	endemic	rare
Psidium guajava L.	guava	non-native	rare
OXALIDACEAE (Wood Sorrel Family)			
Oxalis corniculata L.	'ihi	Polynesian	rare
PLANTAGINACEAE (Plantain Family)			
Plantago lanceolata L.	narrow-leaved plantain	non-native	common
POLYGALACEAE (Milkwort Family)			
Polygala paniculata L.	-------------------	non-native	uncommon
PORTULACACEAE (Purslane Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Portulaca oleracea L.	pigweed	non-native	rare
PRIMULACEAE (Primrose Family)			
Anagallis arvensis L.	scarlet pimpernel	non-native	rare
PROTEACEAE (Protea Family)			
Grevillea robusta A. Cunn. ex R. Br.	silk oak	non-native	rare
ROSACEAE (Rose Family)			
Osteomeles anthyllidifolia (Sm.) Lindl.	'ūlei	indigenous	common
SANTALACEAE (Sandalwood Family)			
*Santalum ellipticum*Gaud.	'iliahi alo'e	endemic	uncommon
SAPINDACEAE (Soapberry Family)			
Dodonaea viscosa Jacq.	'a'ali'i	indigenous	uncommon
SOLANACEAE (Nightshade Family)			
Solanum lycopersicum L.	cherry tomato	non-native	rare
THYMELAEACEAE ('Akia Family)			
Wikstroemia oahuensis(A.Gray) Rock	'akia	endemic	uncommon
VERBENACEAE (Verbena Family)			
Lantana camara L.	lantana	non-native	rare
Stachytarpheta jamaicensis (L.) Vahl	Jamaica vervain	non-native	uncommon



January 2009 Project area
Post-Fire Botanical Survey and Assessment

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Appendix 10

KAHEAWA WIND POWER II

POST-CONSTRUCTION REVEGETATION AND RESTORATION PLAN

January 2009

Introduction and Summary

Kaheawa Wind Power II, LLC (KWP II) proposes to construct and operate a new 21-megawatt (MW) wind energy generation facility at Kaheawa Pastures above Māʽalaea in the southwestern portion of the Island of Maui, Hawaiʽi. The proposed project is situated on approximately 333 acres (135 ha) of Conservation District Land (State of Hawaii, DLNR) immediately adjacent to the existing 30-MW Kaheawa Wind Power (KWP) project operated and owned by Kaheawa Wind Power LLC (KWP LLC) (Kaheawa Wind Power II 2009).

Approximately 65 acres (26.1 ha) of land may be disturbed during construction of the KWP II facility. The disturbed area is former pasture that was converted from native plant communities well over 100 years ago, and is currently dominated by a mixture of native and non-native grasses and low shrubs with scattered small trees. The area is subject to periodic burning, which suppresses native plant elements and favors the spread of non-native fire-tolerant grasses. Native plants are limited to a few scattered individuals. A recent botanical inventory indicates that native plant species are spread throughout the project area, mixed among the grasses, but are less prevalent at the lower, drier parts of the property where fires have occurred more recently (Hobdy 2009).

This plan is intended to meet the dual objectives of stabilizing disturbed areas immediately following construction, and a longer-term effort to re-introduce and establish several native plant species throughout the site. Most elements of this plan are derived from experiences and lessons learned at the adjacent KWP project site, which underwent construction in early 2006, and which has a comparable plant ecological history.

Existing Conditions

The proposed KWP II project area is located in an area known locally as Kaheawa Pastures, on the southern slope of the mountains of West Maui between 1,440 and 2,880 ft elevation (439 and 878 m). The project area is approximately 4 miles (6.4 km) mauka (inland) of McGregor Point. It is located in the General subzone of the State Conservation District to the west of the existing KWP facility.

Average annual rainfall at the proposed project site ranges from less than 15 inches per year at the Honoapiʽilani Highway/site access road intersection to slightly over 40 inches per year at the uppermost portion of the existing wind facility (3,200 ft). Most of the rainfall occurs during winter months (80+ percent from November through April).

Botanical surveys of the proposed KWP II area were conducted by Robert Hobdy in October 2006 and again in January 2009. The second survey was conducted to document re-growth following a wildfire in September 2006 that burned about 80 percent of the 333 acre (135 ha) project area (Hobdy 2006). Hobdy (2009) identified 86 plant species, twenty of which are endemic or indigenous to the Hawaiian Islands. He describes the vegetation as mostly low wind-blown grasses and shrubs with occasional patches of small trees. No state or federally threatened, endangered, or candidate species were found during the surveys.

Background of Revegetation Efforts at KWP

Because of the proximity and similarity of the landscape of the two facilities, the proposed KWP II facility will rely heavily on the lessons learned at KWP. The amended Conservation District Use Permit

(CDUP MA-3103) granted to KWP by the Board of Land and Natural Resources (BLNR) on 24 June 2005 contained the following conditions related to revegetation:

20. *"All cleared areas shall be revegetated in a manner consistent with other permit conditions, with specific consideration given to the fire contingency plan and the Habitat Conservation Plan. Any necessary revegetation shall be completed within thirty days of the completion of specific project components that resulted in ground clearing, using native species found in the area;"*

37. *"The applicant shall ensure that operations and maintenance staff do not damage native plants. If construction or operation required the removal of native plants, the plants will be removed, relocated and replanted. The applicant shall pay for the cost of this effort;"*

38. *"The applicant shall work with plant experts to introduce appropriate native plant species back into the Kaheawa Pastures;"*

Similar conditions were required in the NPDES General Permit for the KWP project area:

- *"Temporary soil stabilization with appropriate vegetation will be applied to areas remaining unfinished for more than 30 days; and*

- *Permanent soil stabilization will be applied as soon as practical after final grading. Contractor will coordinate with the Department of Land and Natural Resources (DLNR) regarding selection of appropriate vegetation as a condition of the Conservation District Use Permit."*

After extensive research and efforts at seeking source materials, KWP concluded that establishing vegetation within 30 days by seeding with native species (per Condition 20) would be infeasible due to the unavailability of native species in sufficient commercial quantities. For example, the Hawai'i Department of Transportation is working with the Federal Highway Administration on a three-year research project to develop native grass mixes and hydro-seeding techniques for use on civil projects in Hawai'i. However, techniques have not yet been developed in Hawai'i for hydro-seeding or broadcasting with native seed mixes on a large scale.

In the *Response to October 27, 2005 Letter Regarding the Establishment of Stabilizing Vegetation Cover for Erosion and Sediment Control Related to Wind Farm Access Road Construction*, The State of Hawai'i Department of Land and Natural Resources (DLNR) authorized KWP's request to apply commercially available annual rye (*Lolium multiflorum*) in order to comply with permit conditions of the CDUP and the NPDES permit, given the flowing conditions:

1. *"The permittee shall acquire commercial quantities of native pili grass bundles or other native species as soon as possible to substitute the annual rye; and*

2. *The permittee is responsible for controlling the annual rye if it starts invading adjacent State lands."*

KWP subsequently established a conservation partnership with the USDA/NRCS to obtain native Pili grass (*Heteropogon contortus*) from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) Plant Materials Center on Moloka'i. This partnership resulted in field trials to test the ability to establish Pili grass at KWP using seed and bales. Following several treatments, it was determined that while it is possible to establish Pili in limited quantities, and over several months, it probably cannot be expected to meet rapid, site-wide ground cover re-establishment requirements.

Following the trials with Pili grass, KWP petitioned DLNR and the Office of Conservation of Coastal Lands (OCCL) to consider allowing manual application and hydro-seeding with a combination of Kikuyu grass (*Pennisetum clandestinum*), a non-invasive naturalized grass, and Annual rye to accomplish site revegetation goals. Benefits of the Kikuyu grass-Annual rye mixture include rapid soil cover, reduced soil erosion, improved soil organic matter levels, increased water infiltration, weed suppression, and improved conditions for recruitment of native species. DLNR Forestry and Wildlife officials provided comments on this proposal, citing that Annual rye is expected to die off and provide a more suitable environment for recruitment by adjacent species and that both Kikuyu and Annual rye are desirable in a fire-prone setting. The wildlife section expressed interest in limiting the amount of emergent grass in the immediate vicinity of turbines, while providing recommendations to minimize the attraction of Nene, which are common in the area and browse on a wide range of vegetation types, including Kikuyu. This request is currently pending a decision by OCCL. KWP biologists have documented that Nene are prevalent in the area and currently use the areas in proximity to the turbines on a regular (i.e., almost daily) basis. Thus, revegetating bare areas with a Kikuyu/rye mixture is unlikely to pose an additional risk of bird collisions.

At the same time, KWP has had considerable success at re-introducing native plants grown in the nursery at various locations throughout the site, including along cut and fill slopes and other open earth portions of the roadsides and turbine pads. Although these plantings do not provide a uniform stabilizing cover *per se*, it does appear that they will, over several seasons, come to dominate the areas treated. Between July 2007 and June 2008, approximately 7,500 young aʻaliʻi (*Dodonaea viscosa*) were propagated from seed collected at Kaheawa and planted along cut and fill slopes and other open earth portions of the roadsides and turbine pads. An intensive out-planting effort comprising nearly 16,000 individual plants of several key native species is underway during the winter of 2009.

Project Goals & Timeline

Permits for KWP II have not yet been granted, so for the purposes of the draft EIS and HCP, the goals of the revegetation plan for KWP II are based on the relevant CDUP and NPDES permit conditions for KWP, as well as experiences and lessons learned at KWP.

The proposed revegetation strategy for KWP II has two goals:

1. Address the immediate requirement of stabilizing exposed soils following construction activities at KWP II, in accordance with erosion and sedimentation control Best Management Practices and National Pollutant Discharge Elimination System (NPDES) stormwater discharge permitting requirements; and

2. Set forth a plan for re-introducing native plant elements in selected areas throughout the site over several years, with the goal of re-establishing native plant elements in areas that have been overgrown with non-native species for a century or more.

To accomplish the short-term goal, KWP II proposes to apply a relatively fast-growing mixture of grasses that will enable the establishment of surface vegetation after ground shaping and grading activities have been completed. Areas to be revegetated following construction will be treated with a hydro-mulch and seeding mix of Annual rye and Kikuyu grass. The primary purpose of this approach is to stabilize exposed soil and prevent erosion along road cuts and fill slopes using a suitable cover that has a high likelihood of success. This phase is expected to last for up to several months following construction and will require supplemental irrigation and monitoring to ensure establishment of stabilizing cover.

To accomplish the long-term goal, KWP II proposes to re-introduce native plants in discrete locations over several years, with the intent of eventually re-establishing some of the key elements of the plant communities that historically existed on the site. As at KWP, this phase will involve propagating native plant specimens from seeds and cuttings collected in the area and subsequent out-planting.

Short-term revegetation will follow immediately after construction of the access roads and turbine foundations, while long-term revegetation will occur during the first several years of the project. The two approaches are discussed in more detail below.

Immediate Revegetation to Improve Soil Retention and Prevent Erosion

KWP II will apply a hydro-seed mixture of Annual rye and Kikuyu grass to areas of exposed soil along the edges of turbine pads and along road cuts and fill slopes to provide immediate stabilization. Kikuyu grass, a naturalized species that occurs at the Kaheawa Pastures, is believed to emerge quickly and becomes easily established as a ground cover, and can be procured in commercial quantities and form that are suitable for this type of application. Incorporating Annual rye grass into the seed mixture is expected to provide a more rapid cover, and allow the rye grass to be naturally over-taken by the Kikuyu and neighboring species. Annual rye is readily available for hydro-seeding and emerges more quickly than many other ground cover species.

Although not suitable for establishing the kind of rapid cover needed for immediate stabilization, Pili grass propagated in local nurseries has been successfully transplanted to cut and fill slopes at KWP and is considered one of the principle species that will be used to supplement immediate revegetation requirements at KWP II, while also providing a long-term benefit. The Kahoolawe Island Reserve Commission (KIRC) has been implementing a successful restoration program on the island of Kahoolawe using Pili grass to reduce soil erosion and promote the recovery of native botanical communities on substantial portions of the island. The NRCS Plant Materials Center on Molokai has been instrumental in providing support for the KIRC's efforts by supplying commercial quantities of Pili grass in bale form to be used for a variety of soil stabilization applications. KWP II is working collaboratively with KWP and the NRCS to coordinate and implement similar measures for use in both immediate and longer term revegetation strategies.

Mechanized hydro-seeding along a bare road cut during immediate site revegetation and soil stabilization efforts following construction at KWP.

Long-term Revegetation Using Native Species Common in the Area

KWP II plans to approach this phase of the site revegetation plan in a manner that emulates the successful native plant reintroduction efforts at KWP. This will include collection of native seed on-site and propagation at local nurseries. Native species currently being collected at KWP and successfully propagated at local native plant nurseries on Maui include ʻakia (*Wikstroemia oahuensis*), koʻokoʻolau (*Bidens mauiensis*), ʻaʻaliʻi (*Dodonaea viscosa*), ʻulei (*Osteomeles anthyllidifolia*), ʻōhiʻa (*Metrosideros polymorpha*), and ʻilima (*Sida fallix*). These are relatively fast-growing and easily propagated low-stature species and provide excellent root structure for maintaining surface substrate retention and promoting important native elements of the vegetation community.

Because they will come later, many of these plantings will be installed in areas that were previously stabilized with the Kikuyu/rye mixture. In the case of the taller shrub species, the objective will be to have them eventually establish as a shrub layer that is taller than, and partially shading out, the shorter grass layer. Some areas will also be planted with Pili grass, either immediately following construction, or in later years, or other lower growing shrubs and vines. In such cases, it may be necessary to clear some areas of established grass cover, either manually or with the assistance of an approved herbicide. Any use of herbicides would be done only in consultation with DLNR, and only in accordance with applicable restrictions on handling and use.

KWP II will work in collaboration with KWP to share resources and coordinate logistics. KWP II plans to work closely with specialists that may advise and help select areas to be revegetated to ensure the best representation of target conditions for the long-term effort.

Due to the current prevalence of mostly non-native species at the site, revegetation efforts for KWP II are expected to enhance the biological integrity of the region beyond its present condition.

Several native plant species successfully nursery-propagated and out-planted on a turbine fill slope at KWP as part of long-term revegetation efforts.

Monitoring & Success Criteria

Regular irrigation and monitoring will be necessary at KWP II to ensure that immediate revegetation measures are successful. Young grasses are especially vulnerable to root damage in the absence of rain or watering. This phase of the project will be considered successful if it can be demonstrated that >75% of the bare areas, fill slopes, and road cut segments that receive treatment have established cover within one year following treatment. If initial applications appear to be only partially successful, subsequent hand and/or hydro-seeding applications will be performed to ensure adequate coverage.

The longer term revegetation efforts at KWP II are expected to be very successful given the success at KWP. A well-established seed collection and propagation program exists in cooperation with local nurseries, other native plant specialists, contract landscape specialists, and volunteers. Plants will be out-planted and maintained, monitored and documented using resources available at KWP II and in collaboration with community and conservation groups. This effort will be considered to be successful if a minimum of 60,000 plant specimens are installed during the first three years following construction, with an average survival rate of greater than 75% (i.e., a minimum of 45,000 surviving plants), for all plants one year after installation, as determined by representative sampling of planted areas. If mortality exceeds 25%, replacement plantings will be installed as needed to achieve the 75% minimum.

In addition, KWP II will work alongside DLNR Forestry and Wildlife specialists to ensure that revegetation initiatives consider and incorporate all wildlife, forestry, fire and rangeland concerns and are in alignment with the management provisions of the Conservation District.

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Appendix 11

An Assessment of Hawaiian Native Molluscan Fauna
Kaheawa Pastures, West Maui, Hawaii

TMK 4-8-001:001 and 3-6-001:014

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Introduction:

The terrestrial mollscan fauna of Hawai‘i is in a state of catastrophic decline in which hundreds of species and an endemic family are in danger of extinction. Hawai‘i's mollusks evolved in isolation with an ecological naivety that has left them extremely vulnerable to environmental change, and a low fecundity that has not allowed them to recover from the pressures exerted by introduced predators. During the late 20th century perhaps as many as two-thirds of the living species described in the 19th and early 20th centuries have become rare or extinct.

This survey was commissioned by First Wind to determine if any species of native Hawaiian snails, particularly those species federally and state listed as threatened, endangered, or of substantial conservation concern, remain within or along the borders of the Kaheawa Pasture, and if so what steps could be taken to insure their continued survival. The survey area was restricted to former pasture south and west of the present First Wind facility at Kaheawa Wind Power (KWP) and turbine access road, several small ravines and the upper edge of Papalaua Gulch along the upper pasture.

During the survey tree leaves and bark were examined and rock talus was searched for living snails. Soil, mosses and leaf litter samples were screened for living and dead snails to 1 mm in diameter, and exposed ground in gulches and road cuts was searched for fresh and dead shells. No evidence of snails, fossil or extant, native or introduced, was found.

Site Description:

Kaheawa Pasture lies in the Lahaina District in the ahupua‘a of Ukumehame and is defined by the upper reaches of Papalaua Gulch and its tributaries on the west and by Manawainui Gulch to the east and south. The upper elevation of the survey area was approximately 2,700 ft and the lower elevation approximately 1,800 ft. Much of the pasture was burned in 2006 in the most recent of many wind-driven fires to pass through the area. The fire was contained by a firebreak road across the pasture creating two biogeographically distinct areas – the lower pasture which had burned and the upper which had not. There are small stands of ironwood trees throughout the area which have recovered, and in fact benefited, from the fire by spreading.

Water flowing from the pasture into Papalaua Gulch on the west and its tributary gulches on the southwest has exposed the underlying stratigraphy of the pasture in the banks of the gulches. Much of the stratigraphy is relatively constant in appearance with a brown layer of recent soil resting on several layers of hard packed reddish-brown soil-like material, which in turn rests on a cream-colored layer of volcanic grit formed by decaying rock and cinder. The upper two layers are of particular interest because they are the most likely to contain semi-fossil shells of recent species.

The topography of the lower elevations of the survey area consists of low ridges which fan out downhill to the south defining the southern end of the survey area. The ridges and shallow gulches are strewn with large rocks and boulders and the vegetation consists of low grasses and several species of native shrubs and trees about a meter tall. There was virtually no leaf liter accumulation and fire-blackened woody plants could still be seen among the grasses. In this area the search focused on protected places beneath and among boulders where snail shells may have escaped incineration during the fire.

The southwestern edge of the pasture is bordered by a saw-toothed pattern of small gulches and ravines with steep banks devoid of vegetation. These banks were searched exhaustively for semi-fossil shell deposits that might be eroding out of the bare sides of the gulch and for fresh dead shells that may have fallen down from the pasture grasses above. The longest of these gulches bisects the pasture from the southwest to the turbine access road providing a potential catch for snail shells, but none were found.

A couple hundred meters above this bisecting gulch a road had been cut across the pasture in 2006 to form a firebreak from the turbine access road to the edge of Papalaua Gulch. The road formed a convenient transect of the deep grasses of the unburned pasture. When combined, the road and the gulch below provided an unusually complete cross section of the survey area.

The western edge of the pasture is defined by the precipitous Papalaua Gulch, which abruptly terminates the gently sloped upper pasture. In the pasture along the edge of Papalaua Gulch large shrubs and small trees are numerous with some having moist leaf liter beneath them, which was sampled and screened. The unburned grass is nearly chest high and small ‘ohia trees, which are good snail habitat, stand above the grasses and can be found well into the pasture.

Biological History:

Prior to European contact much of the pasture area was probably blanketed by the horizontally growing uluhe fern with scattered trees, predominantly ‘ohia, as on nearby ridges today.

Uluhe fern often acts as a fringe forest plant on mountain slopes and ridge tops. It is intermediate between the forest and the lowland vegetation and is often the dominant plant in that role. Because of the steep inclination of the ridges of West Maui's lee side, uluhe forms an obvious broken line of bright green on the ridge backs beneath the forest. Its regularity in elevation and growth patterns permits a reasonable expectancy from one ridge to the next at the same elevation. Thus by comparing nearby ridges of similar elevation to the Kaheawa Pasture survey area it is possible to imagine what the vegetation of the pasture may have looked like in the past.

It has been my experience that ground-dwelling snails are found in this fringe forest habitat living in the moist leaf liter beneath the uluhe fern, diminishing in numbers with the loss of elevation in the drier, lower portion of the uluhe coverage. Arboreal species are still found today in the higher elevations of the uluhe belt, in geographically well-defined populations on the neighboring ridge on the Wailuku side of Manawainui Gulch.

Since West Maui is heavily eroded into distinct ridges separated by deep valleys, populations of a species living on the ridge tops are isolated and develop characteristics in shape and color unique to each population. Thus if snails had existed in the Kaheawa Pasture they would have had distinct characteristics and would have been interesting to early collectors as subspecies. An intensive search of the collecting data showed that all of the collected variations of the arboreal snail species I would have expected to find in the survey area had data indicating their origin, but none of that data mentions Kaheawa Pasture or Ukumehame.

The nearest location for which there is data for the collection of a snail species is along the ridge overlooking Ukumehame Valley on the trail leading to the reservoirs at Hana‘ula, at a higher elevation, but parallel to the Kaheawa Pasture. There *Partulina fusoidea* was collected and still exists today. It was described in 1855 by Newcomb.

Knowing that collections were made on an adjacent and parallel ridge on the Wailuku side of the survey area in 1855, and that in 1978 semi-fossil *Partulina* were found in the soil along the Wailuku edge of that adjacent pasture at the elevation of the upper survey area, I would expect a subspecies or variation of that species to have lived in the area that the Kaheawa Pasture occupies today. Having no collecting data nor specimens whose location is unaccounted for and could be attributed to the Kaheawa Pasture suggests that the Kaheawa Pasture was unproductive for snail hunters before 1855.

One explanation for the lack of specimens is that the pastoral history of the pasture predates the study of snails in the area. The snail fauna of the pasture can be inferred from surrounding areas, but without living snails or fossil snail deposits it will not be possible to know what the pasture was like prior to what is known historically and what is there today.

Survey Objectives:

This survey and report were initiated out of concern that there may be native snail populations within or reasonably close to the Kaheawa Pastures region and proposed Kaheawa Wind Power II facility. The objectives were to determine if any native land snail species were present in the survey area, to identify them and to try to determine their habitat. Another objective was to look for semi-fossil shells protected beneath rocks or buried in the soil, which could indicate what species might have been present in the area. In the absence of empirical data for the pasture, a list of potential species that may have existed at one time – or through extraordinary circumstances still exist – in the pasture area, has been created for this report.

Species Analysis for Ukumehame

A total of 201 taxa of endemic Hawaiian snails are described from Maui. Of these, 71 taxa are described specifically from West Maui. In addition 27 of the total 201 Maui taxa have data, which does not specifically place them in either East or West Maui and therefore should be included in a list of West Maui taxa. Thus there are a possible 98 taxa of Hawaiian snails, which were or may have been described from West Maui.

Of these 98 taxa, 57 are arboreal and not expected to be represented in the Kaheawa Pasture survey area simply for lack of suitable habitat. Of the remaining 41 taxa of ground-dwelling snails three are known only from fossils.

Of the remaining 38 ground-dwelling taxa I have selected the most likely to have been present in the area of the Kaheawa Pasture before European contact and listed them below. None of the taxa listed below has been recorded in recent years from Ukumehame, collected as fossils near Ukumehame nor found in beach drift between the mouth of Ukumehame Valley and Hekili Point at Olowalu.

The most likely species are the dryland species and subspecies listed in Group One. Those in Group Two are more likely to have been found in more damp situations than exist today, and thus may have been found in the pasture area if it had been covered with uluhe fern as I surmise. Group Three list species found on nearby ridges and valleys and thus may have had a greater range than is known. These are the least likely to have occurred in the surveyed area. In addition, members of the family Endodontidae were probably present and may still exist in talus in the deeper gulches below the pasture, and two species of the genus *Partulina*, one species of *Perdicella* and one species of *Auriculella* still exist on the adjacent ridge discussed above but at a higher elevation than the surveyed area.

Group One:
Amastra (Heteramastra) soror soror (Newcomb, 1854)
Amastra (Heteramastra) soror interjecta Hyatt & Pilsbry, 1911
Amastra (Heteramastra) soror olowaluensis Cooke (?)
Amastra (Heteramastra) subsoror subsoror Hyatt & Pilsbry, 1911

Group Two:
Leptachatina (Leptachatina) fulgida Cooke, 1910
Leptachatina (Leptachatina) praestabilis Cooke, 1910

Group Three:
Amastra (Amastra) lahainana Pilsbry & Cooke, 1914
Amastra (Cycloamastra) metamorpha Pilsbry & Cooke, 1914
Amastra (Cycloamastra) metamorpha debilis Pilsbry & Cooke, 1914
Amastra (Heteramastra) pilsbryi Cooke, 1913

Habitat Requirements

The habitats preferred by the taxa listed above are a moist environment beneath rocks and talus in gulches at lower elevations; in the leaf litter beneath trees and shrubs; in mosses growing on trees and rocks; and beneath thick understory such as uluhe fern at mid-elevations.

Conservation Relevance:

It is highly unlikely that living native snails, including those which receive protection under state or federal endangered species laws will be found in the Kaheawa Pasture. However, all of the native Hawaiian land snails should be considered rare and treated as such if discovered.

Discussion:

There were approximately 1,308 species and subspecies of endemic land snails described from Hawaiʻi. They represent 7 widespread Indo-Pacific families. In addition there is one endemic family which reflects a spectacular divergence from its ancestor over millions of years of evolution in an isolated environment. This family containns 499 taxa representing 38.5% of all known species and subspecies of Hawaiʻi's endemic snail fauna.

Polynesians colonized the islands approximately 2,000 years ago and they appear to have had very little effect on the land snail fauna. It was not until Europeans introduced ranching, large-scale agriculture and global commerce during the past 230 years that the Hawaiian snail fauna began to collapse under the pressure of a new biota that displaced their habitat, and predators that decimated their populations. Today perhaps 90% of the known Hawaiian snail fauna is extinct or is in imminent danger of extinction. Sensitivity to this situation is essential in planning developments anywhere in Hawaiʻi.

The attention First Wind has given to this important but devastated aspect of Hawaiian biology is commendable, but it appears that years of abuse of the land, along with tell-tale hints of pastoral use pointing back to before the 1850's, seem to have reduced the area to a molluscan desert.

Conclusions:

I am confident there are no living native snails within the area surveyed. Without evidence, not even one fragment of a shell, and with no historic description of the area or collecting data from a snail species within the survey area, there is nothing to do but speculate on what might have existed in the survey area in the past. I have done this using fossils collected from several sites on Maui and Lanaʻi, by examining sorted beach drift taken over 15 years and by examining collecting data taken from the data slips of specimens held in several museums worldwide.

Relavant Citations:

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